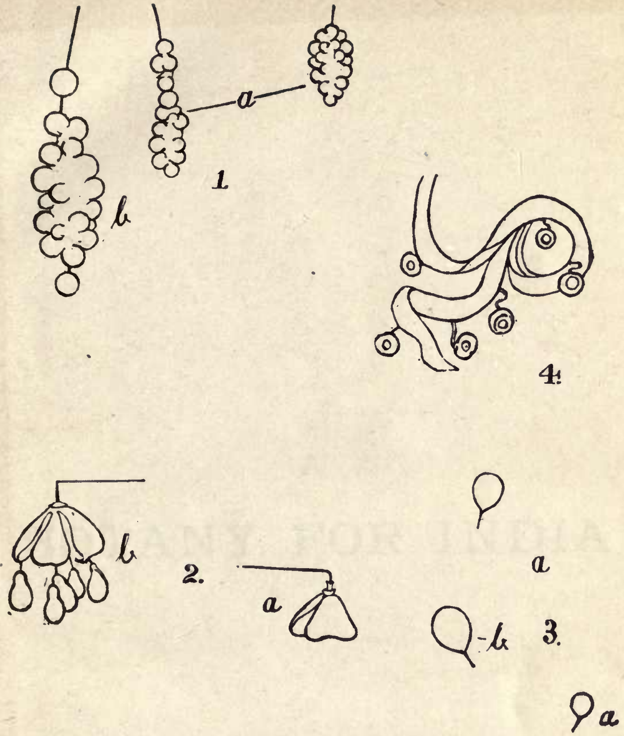

The concealment of unripe and the display of ripe fruits and seeds: a. the unripe, b. the ripe fruit in each case.

1. Smilax aspera, L.
2. Euonymus crenulatus, Wall. The seeds have large yellow arils and remain hanging from to the brilliantly coloured pod.
3. Osyris arborea, Wall.
4. Acacia melanoxylon, R. Br. The black seeds are rendered more conspicuous by the long red, fleshy funicles, and remain attached to the pod for some time.

A
BOTANY FOR INDIA

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BY

P. F. FYSON, B.A., F.L.S.
Indian Educational Service

UNIV. OF CALIFORNIA

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IN MEMORIAM
Richard M. Holman

PREFACE

THERE are many excellent textbooks of Botany suitable for students of all stages, but nearly all deal with European plants alone or are written from the ... there are many

ERRATUM

Page 182 line 1 *for* branches *read* leaves

well known by name and can ... not figured, or only sufficiently so for identification; on the other hand, difficult points, like those in the flowers of orchids and grasses, are shown, it is hoped,

[1] This word is, as far as I know, new, but seems so obvious a designation of the habit of flowering once after many years, that it may not be so. The only reference I have seen to the habit by name is in Warming's *Lehbuch de Algemeine Botanik* where such plants are called Pleiocyklishe Gewäsche (S. 72). In view of the commonly accepted term, biennial, for plants of two seasons, multiennial would seem more natural to English readers.

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PREFACE

THERE are many excellent textbooks of Botany suitable for students of all stages, but nearly all deal with European plants alone or are written from the standpoint of European botany; and there are many little points in which a Botany founded on tropical plants would differ, as instance the absence of well protected winter elementary buds, the fewness of biennials, and the much greater importance of what I have called multiennials[1] and of succulents.

This book has, therefore, been written for those beginning Botany in India, and an attempt has been made to treat the subject from a tropical standpoint.

Since no illustrations, however perfect in detail, can take the place of actual specimens, plants which are well known by name and can easily be procured are not figured, or only sufficiently so for identification; on the other hand, difficult points, like those in the flowers of orchids and grasses, are shown, it is hoped,

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in sufficient detail to render the explanation of a specimen clear.

Another difference from many books on the morphology of plants will be found in the fewness of technical terms, only those in common use for descriptive purposes being given. Special names, which like hesperidium and caryopsis are peculiar to their Orders, are excluded, because it is considered of more importance that the student should recognize the real nature of the things they designate as special forms of the standard types than learn distinctive names for them. On the other hand the distribution of fruits and seeds is treated more fully, perhaps, than usual, especially as regards the part played by colour.

The internal structure and histology of plants is not dealt with in this volume.

Part II is an introduction to the classification of flowering plants, and only those orders which are well represented in the tropics, or are for other reasons considered of sufficient importance, have been treated. The plan followed has been to describe common, well-known plants and deduce from them the characters of the order. In the concluding chapter an indication, necessarily imperfect because of the fewness of the orders dealt with, is made of the grouping of the Natural Orders, and stress is laid on the vegetative characters distinguishing them.

The illustrations have all been drawn specially for this work. Fig. 3 shows an adaptation of an apparatus designed by Dr. Detmer and sold by Messrs. Gallenkamp & Co., London. The inference drawn in the text, that the maintenance of the same level in the tube

B shows that the quantity of oxygen absorbed is about the same as that of the carbon-dioxide given out, is only approximately true in the case of seeds, and hardly justified, perhaps, by the results of this particular experiment, for analysis of the gases in the tubes appears to show that respiration ceases in B when the concentration of CO_2 has reached 10–15 per cent. The statement is, however, true for ordinary respiration.

P. F. F.

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† Wrongly printed Labiateæ in the text.

PART I

GENERAL BOTANY

CHAPTER I

INTRODUCTION

THE world in which we live comprises two separate and distinct classes of things—the **animate** and the **inanimate,** the living and the not-living. By animate things we mean those which like animals and plants feed, grow and reproduce each his own kind. The not-living include rocks and stones, soil, water and air. These may, indeed, be changed one into another, for by the sun's heat and rain, the solid rock of which this earth is composed is broken up into the smaller pieces we call stones, and these again are still further broken up and changed by rain and air into soil. Water when warmed by the heat of the sun or of a fire may be converted into an invisible vapour, which passes away and mixes with the atmosphere, and when cooled condenses and falls down again as rain. But though these transformations are readily brought about, no one would say that these substances feed and grow and reproduce their kind in the same sense that animals and plants do.

Living things are divided into two great groups or **kingdoms**—the **animal** and the **vegetable**—which, as far

at any rate as the plants and animals that we can see with our eyes are concerned, are so distinct that it is difficult to believe that they are in any way connected. Animals move from place to place in search of food; plants are fixed in the ground. Plants are green, or rather they have green leaves, while animals are seldom green but may be of almost any other colour, red, yellow, brown, black or white. This distinction, though it may seem to be trivial enough, is really, as we shall see later, of very great and fundamental importance. And in their general form or shape animals and plants seem to be constructed on different plans. There is a symmetry about an animal's body which is absent in the case of plants. In external appearance the right and left sides of most animals are exactly the same. A bird, for instance, has a wing on each side, a horse, dog or cow two legs on each side. With smaller animals we find the limbs, even where, as in the centipede, there are a very large number, arranged evenly on either side of the body, while the head and the tail are exactly in the middle line. But in a plant there is none of this symmetry. Its leaves indeed are generally all alike, and its flowers are not only all alike, but each in itself is symmetrical about some line, but plants of the same kind have not all the same number of branches and some may be developed more on one side than on the other, for external circumstances influence the general shape very much. In their method of feeding and in their internal structure animals and plants are also entirely distinct. There is, for instance, in a plant nothing to correspond to the stomach or to the heart of an animal, but of this we shall learn more later on.

Each of these two kingdoms has its own separate science or study and **Botany** is the name given to the science of the vegetable kingdom. It means the study of plants, their shape, structure, mode of living and of reproduction, and relationship one to another.

By far the greater number of what we ordinarily think of as plants have flowers and seeds. But there are some that have not, and yet are every bit as much plants. Ferns, for instance, have no flowers, nor have the Selaginellas and Mosses which grow commonly among the ferns of our gardens and in damp cool places on the mountains of India. There are plants too of very much simpler nature. We may often see on the water of our tanks and stagnant rivers floating lumps of green matter, which are composed of numerous very small plants that have no flowers nor even leaves. Other plants of the same kind form the slimy green matter which we nearly always find where walls or stones are constantly moist, as on the side of a well or standpipe or under the drain pipe of a house. Some minute plants grow so plentifully in temple tanks that they make the water appear quite green. There are yet other plants which are not green, and some so small that they can be seen only with the aid of a very powerful microscope, but on account of the nature and mode of life are classed in the vegetable kingdom. But none of these possess flowers or seeds.

The whole vegetable kingdom is therefore divided into two main groups—the **flowering plants** and the **flowerless.** In the first group are all our ordinary trees, shrubs, garden flowers and field crops, such

as the Mango, Palm, Cotton plant, Tobacco plant, Wheat and Paddy; the second group includes Ferns, Mosses, and practically every minute green or colourless living body that does not move about as an animal does. It is of the first of these two groups, the **flowering plants,** that we shall deal in this book, and only in their external appearance; for the study of their internal structure and of the flowerless plants requires the use of a compound microscope and should properly be taken afterwards.

CHAPTER II

THE NORMAL PLANT

1. Dig up any small plant from the ground and shake it free of most of the soil. It consists, you will see, of two distinct parts: the upper is green or brown and has flat green leaves; the lower is of a dirty white or brown colour and has no leaves.

This lower part, which was in the ground, is called the **root,** and it is divided into thinner and thinner branches as it passes downwards into the soil. The smaller of these branches are often called rootlets, and the soil, you will see, adheres very tightly to the rootlets, especially to their ends, so tightly in fact that, unless the soil is very loose, it is impossible to get it all off except by careful washing in water. And if a plant be forcibly pulled up out of ordinary soil, the roots will always break, the greater part remaining in the ground.

The upper part is called the **shoot** and consists of a round or rectangular **axis** which is also branched, but it differs from the root in having flat green leaves. The main axis is generally called the **stem,** and both it and the branches may have leaves, and always do have leaves when the plant is young.

2. Examine now a young thin branch of Bamboo, a Balsam, or a Marvel-of-Peru plant. In the first the leaf is divided into two parts—the upper flat, the lower encircling the axis. In all three where the leaf or leaf-stalk joins on to the axis, the latter is swollen and harder than the rest. This hard, swollen part is called a **node,** and the part of the axis between two nodes is called the **internode.**

Now examine a plant of OCIMUM the Basil, or VINCA the Periwinkle, or ZINNIA, or a branch of IXORA, Coffee, Guava, or Pomegranate tree. The leaves are placed not singly, as in grass or Bamboo, but in pairs, one on each side of the axis. The part of the axis whence they arise is again slightly swollen, so that in these, too, there are distinct nodes and internodes.

In the ordinary garden Begonia the leaves are all attached to the plant singly, and there are again distinct nodes and internodes. In the Sunflower, CROTOLARIA, HIBISCUS and many other plants, though the axis is not swollen where the leaves are attached, these points are still called nodes, and the parts between them internodes.

Examine carefully a number of plants and notice that we never find the leaves borne on one part of the shoot in pairs and on another part singly. The arrangement is the same all over the plant, and also in all plants of the same kind. It is, therefore, characteristic of the plant, and of the **kind** of plant, and is of great importance in the study of botany.

When the leaves are borne singly, they are said to be **alternate,** when in pairs **opposite,** and when three

or four, or more, arise together at a node, they are said to be **whorled.**

From the older parts of the shoot the leaves have perhaps fallen off, but where each was, a mark is left or scar—the **leaf-scar.** As the stem grows and increases in thickness, the surface becomes dry and cracked and often peels off, so that it is impossible to see the leaf-scars; but in some trees, e.g. FICUS RELIGIOSA, the Peepul or Bo tree, in the well-known ODINA WOODIER in INGA DULCE and some others, these scars become slits extending almost round the branches even when they are a foot thick.

Observe the ends of the branches of any tree at the beginning of the hot weather when the young leaves are forming, and notice that each leaf at first arches over and covers the tip of the branch, and as it unfolds and, turning backwards, spreads out to the light, the internode between it and the next one lengthens. The tip of the branch is in fact covered by a number of young leaves with very short internodes between them, and is often in consequence slightly swollen. This swollen end is termed a **bud,** and if you examine the branches when the buds are opening, you will see that they grow in length by the lengthening of the internodes which were inside the bud; so that if the bud is destroyed, the growth of the branch is stopped. It is for this reason that the tips of the shoot are protected by the leaves of the bud, and for further protection these leaves are often hairy or sticky, and sometimes the outer ones are changed into tough and hard scales, termed **bud scales.** In some trees that grow in the even climate of the tropics, the tip does

not need so much protection, and is almost bare. But we shall generally find that, if there are no leaves or bud scales, the tip is covered by a thick matting of brown hairs.

By watching the ends of the branches when the buds are unfolding, we can see them actually growing in length, an inch or two perhaps in a week if there has been rain, and we can see that a branch is literally made up of internodes separated by short leaf-bearing nodes. The same is true of the main axis—the stem—and in fact of the whole shoot portion. Any part may be considered as made up of pieces, each consisting of an internode, a node and its leaf or leaves, and all the pieces are practically identical when first formed.

You should notice that, just below the point where a side-branch arises, there is always a leaf, or, if the leaf has fallen, a leaf-scar. Every branch of the shoot arises in the angle between a leaf and the axis, and this angle is termed the **axil.** Examine a number of plants and note that you never find a branch arising except in a leaf-axil, so that the arrangement of the branches is dependent on that of the leaves. If the leaves are alternate, the branches are also alternate; but if opposite or whorled, then the branches are generally opposite or whorled.

Now examine any branch and observe that conversely in the axil of every leaf there is, at least at first, a bud. This may grow out as a branch or remain a mere bud, but there is always a branch or a bud, sometimes hardly larger than a pin's head, in every leaf-axil. This is an important fact, for it enables us

to distinguish between leaves and other organs which may look like leaves.

FIG. 1. RADISH

The root, on the other hand, bears no leaves, and its branches are not arranged like those of the shoot, but in lines. This is very well seen in the common country Radish, which has a thick main root, upon which the rootlets are arranged in two rows, one on each side.

Sow a few Broad-beans in moist earth and keep the soil damp till one or two leaves have appeared. Now pull up the plant and you will see that the rootlets are in four vertical rows, and come out from the inside through slits in the outer surface of the main root. Examine a root of PANDANUS, the Screwpine; there are a very large number of little knobs—really young rootlets—and it is easy to see that they are in rows, running down the root. Here too one can see that the rootlets come out from inside, breaking through the outer surface of the root. This same growing of young roots from inside the parent root can be well seen too in the hanging roots of the Banyan. It is in fact a characteristic of root-branching; in the case

of the shoot, on the other hand, where a branch and leaf are attached to the axis, the surface is unbroken and they appear to spring from its surface and not from inside.

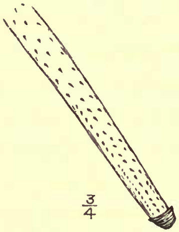

FIG. 2
STILT-ROOT OF PANDANUS

The tip of the root is covered by a sort of cap, the **root-cap,** which we can see very easily on the root of PANDANUS, or the hanging roots of the Banyan, and on plants that float on the water, e.g. TRAPA and PISTIA. The root-cap is not formed of leaves like the covering of the bud, for the root has no leaves, but is a specially developed part of the extreme tip, and spreads backwards from it. On the shoot, generally towards the ends of the branches, the flowers are borne; and after a flower has faded, there is developed in its place a fruit or pod containing one or more seeds.

Flowers and seeds are never produced on the roots. The Ground-nut has pods and seeds under-ground, but the branches on which they are borne spring from and belong to the shoot and are not roots, though they bend down into the soil, and, losing their green colour, seem at first sight to be roots.

We see then that the root and shoot parts of a plant are really quite distinct, differing not only in their colour, but in the nature of their ends and of their branching, and likewise in the absence or presence of leaves and flowers.

CHAPTER III

THE FUNCTIONS OF THE PARTS

1. A plant then consists of definite parts of different and distinct kinds. They are the **organs** of the plant, and, like the organs of our body, have each their own special work or function to perform, though one organ may do more than one kind of work, or the same work may be done by more than one kind of organ.

The study of these functions belongs properly to Physiology, a branch of Botany into which we cannot properly go till we have learnt something about the inner structure of plants, but the more important functions are not difficult to make out. As, however, all ordinary plants grow in the ground, we must first find out the nature of soil.

2. When a pit or well is being dug, the surface soil is usually seen to be a very shallow layer from a couple of inches to a foot in depth. Below it the **subsoil** is nearly always lighter in colour and contains pebbles and stones, which are larger at lower levels, till it merges into solid rock. To find out what soil consists of, put a small quantity in a glass of water, and having stirred it well, leave it a

minute or two to settle. A deposit soon forms at the bottom while the water becomes clearer and on it will be found floating bits of leaves, roots and other organic remains. Skim these off, pour the brown water into a large dish and allow it to evaporate. Add more water to the original deposit, stir it up, and after allowing it to settle a minute or so, pour the water away, and again add water to the remainder. Proceeding in this way you will eventually find at the bottom of the glass hard (probably whitish) grains of sand and rock, while, when the water first poured off has evaporated, a layer of sticky clay will be left on the dish.

From this we learn that surface soil contains (i) organic matter which floats in water, (ii) clay, and (iii) sand. The reason why clay and sand separate is that the former is made up of much finer particles, which because they are so small take longer to sink, and remaining in suspension are removed in the water that is poured away. You may, of course, keep all the water removed at each washing. It will be found that the several washings contain mixtures of clay with gradually increasing proportion of sand.

Doing the same with the subsoil, you will find that there is practically no organic matter, only a few stray bits of root and much less clay, but more sand and bits of rock.

So that we can trace continuous change from the solid rock at the bottom to the soil at the top.

Now the ordinary rock of South India consists of a mixture of silica (which is transparent and glassy in

appearance) and various minerals containing compounds of iron and other metals with alumina and silica. Under the combined effect of the intense heat of day and comparative cooling of night the rock splits and allows water to soak in from above. This water contains carbonic acid (obtained partly from the air while it fell through it as rain, and, still more, from the roots of plants) and also various organic acids produced by the decay of vegetable matter. These acids act on the minerals in the rock, and break them up into simpler compounds. The soluble compounds are carried away below, while the silica, which is insoluble, remains as separate particles of sand, and the insoluble compounds of alumina with silica and certain metals remain as clay, an entirely distinct substance.

Soil, therefore, is produced from the underlying rock by a long process in which the sun's heat, rain water, the carbonic acid of the atmosphere and that given out by the roots, and lastly organic acids produced by the decay of plant remains, all play a part. The action of these agents is continually to wash away the surface soil, and to renew it from below, and there is added the decaying remains of animals and plants—decaying naturally or partially digested and dropped as dung—and these constitute **humus**, a very important constituent of all good soils.

The various kinds of soil differ from each other mostly in the different proportion of these three constituents—sand, clay and organic matter (humus).

In the dry beds and banks of rivers which flow only during the rains, the soil is almost pure sand, because though ordinary rich soil is washed down off

the land by the rapid currents further up stream, where the water flows less quickly, the heavier sand particles in it are dropped to the bottom, while the finer clay and the lighter organic matter are swept further on. For the same reason—that the clay is swept away—the seashore is, if there are no rocks, always sandy. But towards its mouth where a river meets the sea, its current being checked still more, most of the clay is dropped too, so that the action of our rivers is to remove soil from the up-country and hilly tracts, to leave the sand on the plains when they begin to flow slowly, and the finer particles of clay and organic matter near the coast, or wherever the current is checked (e.g. in irrigation works).

Soils differ very much in their physical characters. Every one knows that water easily runs through sand but is retained by clay—a sandy soil is soon dry after rain, while on a clayey soil the water stands in shallow pools. But there is also a considerable difference in the amount of water each will hold. To see this take samples of clay or clayey soil (such as the clay used for bricks and pots or black cotton soil), ordinary garden soil and sand, well dry them in the sun or in an oven, and fill a small vessel say an ollock measure with each, weigh these, then put them severally into large funnels, fitted with a thick filter of blotting paper or a plug of cotton wool to keep the soil from running through, and pour water on till each is thoroughly wet, allow the superfluous water to drain away underneath, and emptying out the wet samples weigh them. You will be surprised to find the enormous difference between the retentiveness of different

kinds of soil, and its dependence on the amount of clay or of organic matter present.

The water is retained between and round the particles, and the smaller the particles, the greater the sum total of their surfaces, and the greater the amount of water retained by the soil.

3. Let us now consider the **root** and its functions.

In the first place a plant is fixed in the ground by its roots. Dig up any plant, or better, take one that is growing in a pot. Carefully remove all the soil, by washing in water, so as not to break more of the rootlets than you can help. Dry them and measure each separate root and rootlet. Add all the measurements together and you will find that the total length of the whole underground portion is immense; it may be even a thousand times the height of the shoot. This means that the soil under a well-grown plant is pierced through and through in all directions by the roots, so that there is not a cubic inch of earth, hardly even a piece the size of a gram seed, but has a rootlet passing through it.

Now put some seeds of Maize or of Mustard on a piece of red blotting-paper, cover them over, and keep the paper damp for three days. At the end of that time roots will have grown out, and round each will appear a glistening white border which, looked at through a magnifying glass, is seen to consist of numerous very thin threads or hairs. These are really extremely fine tubes, and are termed **root-hairs.** They grow only on the youngest parts, i.e. towards the ends of the rootlets, and die off after a while. As the roots make their way through the earth, the

root-hairs grow out and they become firmly attached to the minute particles of soil, so firmly in fact that it is impossible, even by careful washing, to separate them.

It is by the combined effect of all the rootlets passing through and round the smallest lumps of earth, and of the countless root-hairs glued on to the ultimate particles of soil, that a plant is fixed in the ground; and so tightly that you will find if you try that it is hard work for a man to pull up even a small shrub or bush unless the soil is very loose, and even then most of the rootlets break. We can thus understand how it is that the tallest and largest trees are not blown down except by winds of unusual violence or when the ground has been softened by rain.

4. Secondly, as every one knows, plants require water, and the water must be given to the roots. A certain amount can sometimes be absorbed by the leaves, if they are put in water, but only very little.

Take a small plant, and having cleaned it of all soil weigh it. Then put it in a strong sun for a few hours and weigh it again. It will now weigh considerably less. This, of course, is because it has got drier in the sun, and lost water. Now dry it still more over a fire, or in a steam oven, taking care that it is not burnt or even scorched, and that none of it is lost, and weigh it again. There will be a further loss in weight, and you may go on in this way until all the water in the plant has been driven off.

If you do this simple experiment, you will be surprised to find what a large quantity of water a plant contains. At least half the weight of an ordinary woody plant is water. If you do the same with leaves

you will find that they contain a much larger proportion, while a seedling plant may lose on drying as much as ninety per cent of its weight.

When the water is driven off the leaves wither and shrink, and the stem becomes flabby and weak, just as a bicycle tyre does when the air is let out, and for exactly the same reason. The water in the plant is, as it were, pumped tight, like the air in a bicycle tube, and helps to stiffen the weaker parts, especially the leaves, just as the air in the tyre does.

To learn how much water a plant actually requires, take a small pot in which is a well-grown COLEUS, CALADIUM, Sunflower or any leafy plant.

Wrap it round with a thin india-rubber sheet or piece of oiled cloth, tying the sheet round over the top of the pot so that as little as possible of the earth is exposed to the air, and only the shoot itself sticks out. Weigh the whole in the morning, and write the weight down. Weigh it again in the evening; the weight will be less. Add water until it is about the same again and weigh it again, and in the morning, and the next evening and so on.

You will find that every morning the weight is just a little less than it was after the plant had been watered the evening before, and that at the end of the day it is a good deal less. This shows that water is lost by evaporation, and that much more is lost during the day than at night; since the pot and the soil have been covered up by a water-proof sheet, the loss of water must take place through the plant itself.

Now cut off all the leaves, not the branches, and repeat the experiment. There will now be hardly

any loss in weight at the end of the day, from which we learn that it is almost entirely through the leaves that water passes out into the air.

We see, therefore, that the water in the plant is not stationary, but is moving up from the soil through the stem and branches to the leaves, and from the leaves passes out into the air as water-vapour. The actual amount passed up differs, of course, very much, depending on the size of the plant and the number of its leaves, and their nature. Plants which, as a rule, inhabit dry places lose comparatively little water; those which naturally live in damp soil require a great deal.

Empty the pot that you have weighed, and after separating the earth carefully from the rootlets, put the plant and soil back again and water it. You will probably find the next day that the leaves are drooping, however much water you put, and the plant will very likely die. This is because in ordinary soil water does not occur in visible amount, but as very thin films round each particle of soil. It is only the root-hairs, because they attach themselves closely to the smallest particles of soil, that can get this water, and therefore if they are broken the plant is unable to get water (unless the soil is very wet) and therefore suffers.

5. We have already seen that comparatively little water is evaporated from the stem and branches, practically all that is lost passing out from the leaves. But even on these it is not by the whole surface, for they are covered by a very thin but water-proof membrane called the **epidermis** in which

are numerous minute holes too small to be seen by the naked eye or even with the aid of an ordinary magnifying glass. These holes can be opened or shut —as a mouth by its lips—and are called **stomas.** They occur on all the fresh green parts, but especially on the leaves, and mostly on their under sides. Closing when the air is dry, and there is a risk of too great loss of water by evaporation, and opening when it is damp and there is no danger of the leaves withering, they regulate the amount of moisture passed into the air.

As the branch grows, the epidermis peels off, and is replaced by a much thicker brown skin which forms the outside of the **bark,** and in this there are no stomas.

6. When wood is burnt in a fire, there is left, as every one knows, a greyish powder. This may contain a good deal of carbonaceous matter that is not completely burnt, but by roasting it in an open dish, we may obtain at last a nearly white substance which is not altered or diminished by further heating. This fine white powder, called the **ash,** consists of oxides and other compounds of the elements, **potassium, calcium, magnesium, phosphorus, sulphur** and **iron.** Sodium and chlorine are also often present, and in some plants other elements such as aluminium, manganese, zinc and iodine.

By analysis of the ash of a large number of different kinds of plants, it has been found that the first six of the elements named above are always present: and by growing plants in water containing some or all of these in soluble form, it has been found that they

are absolutely necessary to all plants, and that other elements, even such as are chemically very similar, will not do instead.

We may quite easily grow almost any plant in water by filling wide-mouthed jars with water containing salts of these elements in very dilute solution, and fixing young seedlings to corks, so that the roots are always under water. Fresh solution must, of course, be added to make up for what is used up and evaporated, and it is best to keep the roots dark (by covering the sides and tops of the jars with thick brown paper) and to blow or force air through the water occasionally to keep it healthy. Sometimes too the water gets acid and to prevent that it is good to add a little slaked lime (chunam) which will neutralize any excess of acid. About one part in five thousand (of water) of such salts as POTASSIUM NITRATE, MAGNESIUM SULPHATE and CALCIUM PHOSPHATE with the merest trace of FERRIC CHLORIDE will be sufficient. It will be noticed that among these are two elements not mentioned as occurring in the ash—nitrogen and chlorine. Chlorine, it has been found, is not necessary for plant growth, though it appears to help keep the roots healthy, but nitrogen is absolutely necessary, and is in fact in ordinary farming processes the most important of all the elements. It does not occur in well-burnt ash simply because its oxides are volatile and when its compounds are burnt, it passes away in the smoke as nitrogen or its oxides. So we must always add compound of nitrogen to those represented in the ash.

These elements must, of course, enter the plant from the soil—there is no other way—and they are taken

up by the roots in the form of very dilute solutions of chemical salts, such as calcium nitrate, potassium phosphate, magnesium sulphate, sodium chloride.

The solution of these salts must be very dilute, for experiments have shown that if plants are grown in water there must not be more than one part of any of these salts in five thousand of water. It is on this account that such large quantities of water have to be taken up from the soil and passed out again through the leaves into the air. By experiments and careful measurement, it has been found that in India a crop plant such as Cholam requires an immense amount of water, several hundred and even a thousand times its weight to bring it to maturity. As only a very small proportion, less than twenty per cent of its weight, is due to mineral matter, and as a plant cannot get rid of mineral matter that has once been absorbed, the concentration of these salts dissolved in the water taken from the ground must be very low, probably considerably below one part in 10,000.

7. The **functions** of the **root** then are three. First, to fix the plant firmly so that it cannot be blown over by an ordinary wind, or pulled up completely by a grazing animal. Second, to absorb and pass upward from the soil the large quantities of water evaporated daily from the leaves. Third, to take up the necessary mineral substances and solutions and pass them on to the shoot.

8. The living substance of a plant requires air, that is to say, oxygen, just as animals do. We breathe in air; the oxygen of it passes into the blood and is circulated to all parts of the body, where it combines

with the carbon in the living substance of the tissues and forms carbon dioxide which is expelled again from the lungs.

Plants also take in air, which makes its way through the tissues and combines with the carbon of the living substance to form carbondioxide. This process is termed **respiration,** and is continually going on day and night in all the living parts, being most rapid where life is most active. It is, therefore, most easily observed in parts that are growing quickly, such as buds that are just opening, or seeds that are beginning to germinate.

There are many ways in which respiration can be shown. A very simple experiment is as follows.

Take a tall glass jar which is ground at the top to receive a glass stopper or flat glass plate, and fill it about one-third full of germinating barley or paddy-seed, or of flower-buds, or young leaves.

Close it tightly, with vaseline on the glass stopper or plate to make it really air-tight, cover it over to exclude all light, and leave for a day. Do the same with another jar, but first kill the seeds or flower-buds, or whatever it may be, by boiling them in water and then thoroughly drying them. Next day open the first jar and quickly let down into it a small piece of lighted candle.

It will at once go out. This means that there is no oxygen, and that there is carbon dioxide, for carbon dioxide will put out a flame.

Now do the same with the jar containing the dead seeds. The flame burns for a little while, showing that there is some oxygen, and that there is no carbon dioxide.

This proves very clearly that carbon dioxide is produced by the living seeds, flowers or leaves.

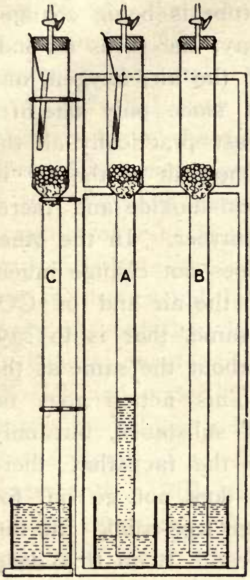

FIG. 3

Fig. 3 shows another apparatus by which we may see that not only is carbon dioxide given out, but almost (though not necessarily quite) the same volume of oxygen is absorbed. C, A and B are three tubes, broader at one end than at the other. We stand the narrower ends in water and put a few pea or bean seeds that have been soaked in water, or some opening flower-buds, in the broad ends of A and B, but in C, any dead seeds or buds, resting them on a little cotton-wool to prevent their falling down into the water. In the tubes C and A we put a short test-tube containing a stick of caustic potash and then close both tubes tightly with good corks. After a little while—in a few minutes if the seeds had first been soaked for a day—the water begins to rise in the tube A, while that in B may fall a little and then remain stationary and in C it does not alter at all. In A the water continues to rise, and will do so (if there is enough caustic potash in the test-tube) till about one-fifth of the whole tube is full of water. But if it be left more than two days, the seeds will begin to ferment and go rotten, and the water to fall down again.

Now caustic potash absorbs carbon dioxide very easily, but not air, so that the rise of water in A must mean that the air in the tube is being changed into carbon dioxide, that is to say, the seeds or buds are absorbing the active part of the air, oxygen, and giving out carbon dioxide. But since only one-fifth of the air is oxygen, and the rest practically all the very inert gas nitrogen, only one-fifth of the air in the tube can be changed to carbon dioxide and therefore the water does not rise further. In the other tube, B, the level of the water does not change much, which means that the volume of the air and of CO_2 in the tube remains about the same, that is to say, the amount of CO_2 given out is about the same as the amount of oxygen absorbed. This action goes on wherever there is actively living substance, but only where it is living, as shown by the fact that there is no change in the tube C. It does not go on, for instance, in the centre of a large tree-trunk, for the wood there is not alive but dead. It is this dead heart-wood, often coloured red or brown, which alone is of any use as timber. But everywhere else in the plant where there is actual life, there respiration goes on.

The CO_2 which is formed makes its way along minute crevices and passages, not tubes, in the tissues, till it gets to the outer surface, either through special cracks in the bark of the smaller branches, or more generally through the stomas.

From the roots it also passes out through the root-hairs, and, dissolved in the water of the soil, helps in the natural breaking up of the mineral substances.

Put a clean fresh shell of a river mussel, or any shellfish—or if there is room, several shells—in a pot of soil, their inner sides facing upwards, and sow seeds in it. After a few weeks take the soil out and examine the shells. On the shining inside surface you will find very thin lines. These are made by the root-hairs, the CO_2 secreted by them dissolving the calcium carbonate of which the shell is composed.

9. We have learnt that wood contains a very small quantity of mineral substances, which are incombustible and constitute the ash, and that these are taken up out of the ground by the roots. But what about the rest, the part that does burn?

The products of ordinary combustion are carbon dioxide and water-vapour. You may prove this quite easily by holding a burning match or splinter of wood in the mouth of a test-tube half full of lime-water (i.e. water with a little freshly roasted chunam in it) for a minute or so, then shaking the tube up. A cloudy appearance, due to the formation of carbonate of lime or chunam, shows that carbon dioxide is produced in the burning.

Now hold over a burning match a clean cold piece of glass or of brightly polished metal. The bright surface will be clouded for just an instant by a deposit of moisture showing that water-vapour is also formed and is condensed by the cold glass. The same cloudy appearance can be seen whenever a cold glass chimney is put on a newly lit paraffin lamp. It passes away at once as the glass becomes warm.

Carbon dioxide and water-vapour therefore are produced by the combustion of wood—that is, by the

solid matter of plants. These are both colourless gases, and smoke is black only because it contains solid particles of carbon that are carried away by the draught before they can be completely burnt.

Now burning means oxidation, and the fact that carbon dioxide and water-vapour are produced when wood is burnt shows that it consists very largely of the two elements carbon and hydrogen. The solid framework of a plant is in fact formed entirely of a substance called **cellulose,** which is a compound or mixture of compounds of hydrogen, oxygen and carbon, in which there are always eight parts of weight of oxygen to one of hydrogen. Starch and sugar, which we obtain only from plants, are also compounds of these three elements (and of no others) and in them too the oxygen and hydrogen are in the proportion of eight to one, the difference being in the amount of carbon, and in the arrangement of the atoms in the molecule.

Because the hydrogen and oxygen are in the same proportion as they are in water, these substances (and others of the same kind) are called by the general name of **carbohydrates.**

Now where does the plant obtain these elements?

Hydrogen and oxygen it gets from the ground as water, but the carbon cannot come from the ground. We cannot burn earth, even that in which plants grow best, and we have only to look at the soil of a paddy or cornfield after the crop has been cut and carried away, to see that except for the roots left behind there is no carbonaceous matter in it at all. Many plants indeed will grow quite well on the sand by the seashore or in waste places where there

is not even a vestige of combustible matter, i.e. of carbon. Strange as it may seem, the whole of the carbon in an ordinary plant, making about one half of the weight of its dry substance, is obtained from the atmosphere. Ordinary air contains, in addition to nitrogen, oxygen, water-vapour and other gases, a very small quantity of carbon dioxide. In ten thousand parts of air there are only four of carbon dioxide, and by weight only three-elevenths of this gas is carbon, so that the amount of this element in the atmosphere is comparatively very small. Still it has been proved by careful experiments that it is from the air and only from it that green plants get their carbon.

All green parts are capable of taking in this carbon, but it is the leaves that are chiefly concerned in this work. The carbon dioxide passes in with the air through the small holes—stomas—through which, as we have already learnt water passes out in the form of vapour, and, making its way through the spaces in the tissues, is absorbed by the living substance of the leaf. There it undergoes chemical change; the carbon is separated from the oxygen, and made to combine with the elements of the water to form a carbohydrate.

This process is termed **assimilation,** and the substance first formed appears to be a kind of sugar. But in most plants this is condensed, so to speak, into **starch,** which, being insoluble in the water of the leaf, occurs as distinct grains, too small however to be seen except with the help of a microscope.

That starch is formed you can prove in this way. Take any thin leaf, such as that of a Tobacco

plant which has been out in the sun. Dip it first into boiling water to kill it, then leave for a few hours in alcohol, which will dissolve out the green colour. When nearly white put it into a strong solution of iodine, made by adding iodine to a solution of potassium-iodide in water. The leaf will turn blue or black, because starch forms with iodine a blue compound. Drop a little of the iodine solution on new white cotton cloth or paper (which usually contains starch) and note the dark blue or black colour.

Some plants, however, will not give this reaction with iodine, because starch is not formed in their leaves, the product of assimilation being sugar. But most ordinary quickly grown plants, which have been in the sunlight for a few hours, will give it.

If you try this experiment with leaves from the same plant which have been plucked in the early morning, you will find that they do not turn such a dark colour, showing that assimilation does not go on during the night, and that the starch formed during the day is passed down into the branches. Being insoluble it has to be first converted into a **sugar** and is passed down in that form to all parts of the shoot and to the roots.

It is only a certain part of the first formed product of assimilation which is converted into starch and sugar, and passed on as such to the rest of the plant. The rest is made to combine with the mineral substances taken up by the root to form with them peculiar chemical compounds known as **proteids.**

Proteids are, as we know, absolutely necessary to animals as food, and they are just as necessary to

the living substance of a plant, only the plant makes them first for itself.

Sow seeds of any quickly-growing herb, and when three or four leaves have appeared on each, cut them all off from some of the plants, leaving the others entire. In a few days the mutilated plants will probably be dead; or if they are still alive after a week, it will be very apparent that they have not grown as those which have still their leaves.

This shows us that the leaves are essential to the life of the plant, that they in fact supply its food.

Now grow in pots some more of the same or any other plant that naturally grows in the open, such as Cotton, Sunn-hemp, or Castor. When they have come up, put some of them out in the sun, giving them plenty of water, and keep the others in a dark room.

In a few days' time those in the dark room will be very likely a little taller, especially if the plant be naturally a climber (the reason for this we shall come to later on), but they will be weak and sickly in appearance, and if left for some time will probably die, while the others will be sturdy and strong and have a healthy green colour.

We learn by this that light is necessary for green plants, and that without light they cannot obtain their food, but starve and die. It is, therefore, only during the day that the making of carbohydrates can go on, and for that reason this process is also called **photosynthesis** (photos = light, synthesis = combination).

Since carbon is taken from the gas carbon dioxide in the process of assimilation, oxygen must be set

free, and this oxygen passes out into the atmosphere again through the stomas; or, in the case of water plants that live always under water and have no stomas, through the whole surface.

This can be shown very easily as follows. Get a clean glass jar nearly fill it with clean water, and add a little ordinary soda-water.

Then put in some healthy water-weed such as you will find at the bottom of any clean tank or channel that is constantly full of water.

Stand the jar in the sun; very soon bubbles of gas will form on the leaves and rise up to the surface. This gas can be easily collected in a test-tube full of water inverted over the weed. Or better still by a glass funnel with a short piece of rubber tube fitting over the tube and closed by a clip. This is let down into the water, with the clip open, till quite submerged and the tube is full of water, then the clip is closed. If the bubbles stop rising add a little more soda-water (which contains carbon dioxide) and they will at once appear again.

When sufficient gas has been collected (it may take an hour or so), take the test-tube out, or open the clip on the funnel, and introduce into the gas a smouldering piece of wood. It will at once burst into flame, showing that the gas is oxygen.

The fact that soda-water contains carbon dioxide, and that instead of that gas we get bubbles of oxygen shows very clearly what the action of the plant is.

Now cover the jar with something that will keep out all the light. The bubbles will at once cease and hardly any gas be collected in the tube.

10. These simple experiments teach us the function of the leaves. In the first place it is through them almost entirely that the water taken up in such large quantities by the roots is sent out again into the air. This large quantity of water is necessary, as we saw, to supply the mineral substances which can only be taken up by the roots in a very dilute solution.

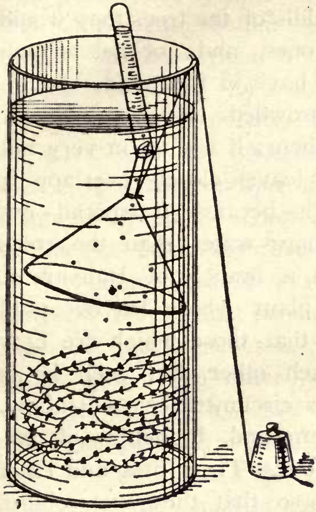

FIG. 4

The second and more important function is the making of the plant's food, that is to say, assimilation of carbon and perhaps also the formation of proteids. These processes take place only in the green parts, and only in sunlight.

And thirdly, through the stomas of the leaves also passes out some of the carbon dioxide produced by respiration of the living substance.

11. In order that leaves may do their work properly they must have plenty of air and light. The more of these they get the more carbon can be assimilated from the air, and the more proteid food substance be made. We see therefore why it is that the branches of most trees and bushes spread so widely, and divide so repeatedly; and why nearly all the leaves are on the smallest branches, and towards their ends, on the outside: so that a well-branched

tree, for instance a Rain-tree, seems like a hollow green dome of leaves supported by its branches. For if there were leaves in the middle of the tree, they would be shaded by the outer ones, and not get enough light, those that were there have in fact died.

Nor are they ever so crowded together that air cannot pass easily between them; it is only in very hot and dry places that we find leaves closely overlapping each other, and then it is because if spread out widely, they would lose more water than the roots could supply. For look at a branch of Banyan or RAUWOLFIA or any other plant whose leaves stand out horizontally, and notice that those which are near together do not overlap each other, but each is as fully exposed to the light as circumstances will allow.

The functions of the stem and branches of the shoot are now easily made out. Their first and chief use is to bear the leaves, so that they may obtain as much light and air as possible. For this reason they must be strong to stand not only the weight of the leaves and of each other, but the pressure of the wind against them. It is on this account that there is in the branches far more cellulose, and that of a harder and stronger kind in the wood than in the leaves.

Most branches are round in cross section, like the main trunk, but when a horizontal branch is rather long and has to be specially strong to support the weight of its leaves, it is often elliptical, thicker in the vertical direction, than in the horizontal. This can be seen in the long branches of Banyan trees, that stretch over a road, and in the Firs and Pines

planted in our hill stations, and sometimes even a tree which has fallen or been forced slantwise away from the perpendicular grows in consequence more quickly in the vertical direction, becoming very much thicker across the vertical diameter.

An equally important function is the conveyance of water and the contained mineral salts from the root to the leaves, and of made-up food materials—sugar and proteids—from the leaves down to all parts of the shoot and the roots.

To prevent loss of water by evaporation, and also for protection against damage by accident or by animals, the stem and branches are covered with a thick waterproof **bark.** The outer part of the bark consists of dead tissue, and its only use appears to be to protect the inner parts against injuries and loss of water; for, not being strong and tough like wood, it does not contribute in the smallest degree to the strength of the part.

We can now understand why leaves are flat and branches and stems cylindrical in shape. The work of a leaf is a surface-work, the greater the surface exposed to the light and air, the greater (other things being equal) the amount of carbon assimilated and of water evaporated. The function of the stem and branches on the other hand is to support the leaves, and to conduct water to them and food from them; so the less the surface exposed to risk of injury and loss of water the better. This is the reason why leaves are thin—thereby having the greatest surface, and branches cylindrical. A stem or a branch may be angular when young, but after a year or so, it always

becomes cylindrical, for that is the form which exposes the least possible surface.

But the lower end of a tree-trunk, where it enters the ground, is very often not round, but very irregular in form and very much expanded, so that a cross-section would be anything but circular. This is particularly the case in very high trees, and these expansions serve to make the stem much more rigid. The extra wastage in dead bark-tissue to cover the expansion is therefore compensated by the increased strength and thickness of the trunk at this part; for it is just near the ground where it is fixed firmly by the roots that the trunk of a tall tree might be broken in a high wind. It may be asked why, if this is the case, the upper part of the stem and branches have not expansions to make them more rigid. The answer is that it is no disadvantage, rather it is an advantage, if the branches bend and yield to a strong wind. It is only at the base where the trunk is fixed by roots firmly into the ground, and therefore cannot give, that it needs extra strength to prevent its being broken.

CHAPTER IV

THE LEAF

1. In chapter ii we spoke of leaves as being either opposite or alternate, but in reality these terms cover a number of slightly differing arrangements.

Opposite leaves.—When leaves are opposite, (i.e. in pairs), the stem is usually, though by no means always, four-sided, and each pair of leaves is then at right angles to the next pair above and below. This arrangement is called **decussate.** When however the leaves stand out to right and left, with, usually, all the blades in one plane, as often happens with branches that are horizontal, they are said to be **bifarious.**

Sometimes we find at a node not two but three leaves, when they are said to be **ternate;** and if there are four or more we speak of them generally as being **whorled,** or 'in whorls' of four or more.

Alternate leaves.—In grasses and all plants of that kind (e.g. all the cereal crop plants) and in some others as HEDYCHIUM (wild Cardamom), and RAVENALA, the 'Traveller's Palm', the leaves are in two rows one on either side of the stem, and stand out to right and left, but not all round it. This arrangement is termed

distichous and corresponds to the bifarious arrangement in opposite leaves.

In CYPERUS, CAREX, and all others of that family, the leaves are in three rows, and if one looks down on the top of a plant (e.g. of the common CYPERUS BULBOSUS, or the Papyrus) the leaves appear as in a spiral, one edge of each at the base being covered by, and the other edge covering, the leaf next above and below. And if starting with any leaf, we take them in ascending order, we find that the third leaf after the one we started with stands exactly over the latter, and the sixth again over both, and the ninth, twelfth, and so on.

In passing round the axis, therefore, we pass through three leaves, or each is separated from the one next above or below by one-third of a circle. Now on every plant with alternate leaves, the leaves are arranged in some sort of spiral, and in the case of PANDANUS, the screw-pine, they give a twisted appearance to the axis. On some plants it is a two-fifths spiral, that is, on going from a leaf to the one exactly above it, we should have to pass five leaves, and wind twice round the axis. Another common arrangement is the three-eighths spiral, in which we must pass three times round the axis, and take eight leaves on the way, before coming to one that is exactly above the first. This we find in LINUM USITATISSIMUM, the Flax plant. There are other spirals with higher numbers which can be easily determined by careful examination.

2. We learnt in chapter iii that the work of the leaves is chiefly to assimilate carbon from the air, and

to build up with it and the mineral substances brought up from the ground, those peculiar complex bodies, carbohydrates and proteids, which are the plant's real food. Since the action of the leaves, depending as it does on light, is a surface one, nearly all leaves are comparatively broad and thin, or at least a part of the leaf is so, and this part is called the **blade.**

Some leaves, like those of the Sunn-hemp and Poppy, consist of nothing else, the broad blade standing out from the shoot-axis without any intervening stalk; such leaves are termed **sessile.**

But in most cases the blade is held out away from the axis by a cylindrical stalk, as in the Mango and Cotton, this stalk being called the **petiole.** In contradistinction to sessile leaves, these are said to be **petioled.**

The end of the petiole where it is attached to the axis is often swollen or broadened out, and is called the **leaf-base.** In some plants the leaf-base is very conspicuous and wraps round the axis. This occurs for instance in the Canna and the Ginger plant. In all grasses and plants like them, e.g. the cereal crop plants and Bamboo, there is no petiole, but only a blade, and a sheathing leaf-base which may be as long as the blade; and except for a slit down the further side completely encircles the stem like a tube. Notice that in these plants there is a fringe of hairs or of thin tissue passing across the leaf at the line where the blade and sheath join.

In others again the base of the petiole is distinctly thickened, and is flexible so that the whole leaf may move up and down. It is then called a **pulvinus.** We shall refer to this again later. A similar swelling

occurs at the junction of blade and sheath in the leaves of MARANTA and PHRYNIUM.

3. In many plants, e.g. Cotton and HIBISCUS, there are on the axis, just at the junction between it and the leaf, two small greenish or brown scales, one on either side of the petiole. These are termed **stipules.** They vary somewhat in shape, and are sometimes so small as to be hardly visible, and often they fall off very quickly, so that one can find them only on the youngest parts, towards the ends of the branches.

In CASSIA AURICULATA (fig. 5) they are large and ear-shaped, from which the name AURICULATA (ear-like) is taken. They are larger still in the common Pea, and being green take the place of the leaf-blade which is changed into a tendril.

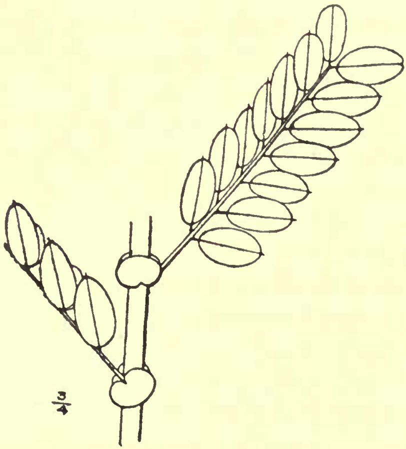

FIG. 5
CASSIA AURICULATA

But in most cases they are narrow and pointed, and less than quarter inch long. In the Coffee plant, in IXORA and others the leaves are opposite, and the stipules of the two leaves are joined together in pairs, to form what looks like one stipule, connecting the two leaves, on each side of the axis. In POLYGONUM

the stipules form a complete sheath surrounding the axis (like the sheath of CYPERUS, but above the point of attachment, not below it).

In the Banyan, Fig, Jak, and a number of other plants the stipules are also in the form of a tube which at first completely surrounds and covers the young bud above the leaf. As the internodes of the bud lengthen and each leaf opens out, the stipule splits into two and is then like the normal pair of stipules but soon falls off, and the only sign left is a scar running round the axis. The same happens with MICHELIA, a plant in every other respect very different from the Banyan. In a few other plants too the stipules are so large that they completely surround the axis, and leave a scar not unlike that of the Banyan or Fig, or of MICHELIA, though not like these, tabular in shape, e.g. in HIBISCUS TILIACEUS (fig. 6).

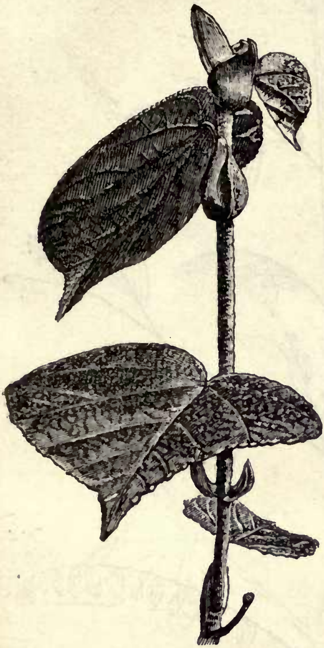

FIG. 6
HIBISCUS TILIACEUS

4. If the blade of a leaf be single and undivided, as, for instance, the Mango, Banyan, Fig, Cotton, Tobacco and Hibiscus, it is said to be **simple.** But if it is

FIG. 7
PHYLLANTHUS NIRURI

divided into a number of small blades connected with the main petiole by their own little stalks, (fig. 5), the leaf is **compound,** and each separate blade is a **leaflet.**

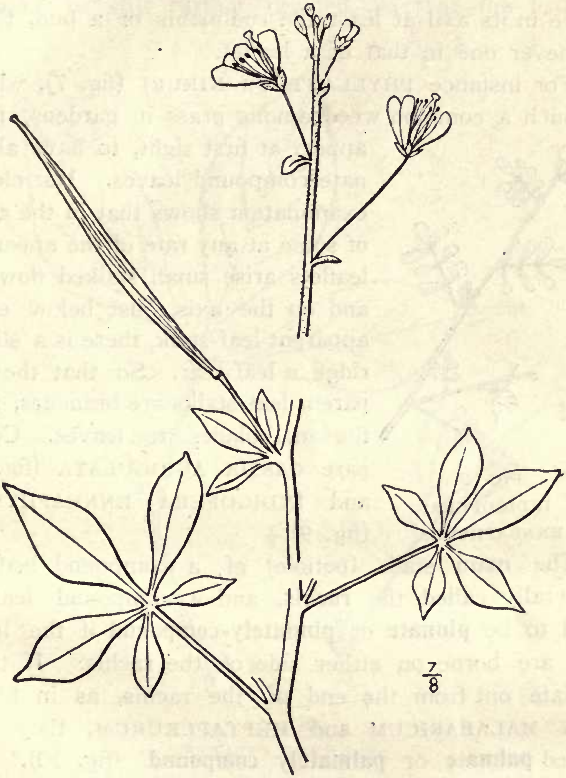

FIG. 8

CLEOME VISCOSA

It may in some cases be at first sight difficult to determine whether one is dealing with a compound leaf or a number of small leaves, but the question can

nearly always be settled without any real difficulty by noting the presence or absence of axillary buds. For while, as we have already learnt, every leaf should have in its axil at least the rudiments of a bud, there is never one in that of a leaflet.

For instance PHYLLANTHUS NIRURI (fig. 7), which is such a common weed among grass in gardens, may appear at first sight, to have alternate compound leaves. But closer examination shows that in the axils of some at any rate of the apparent leaflets arise small stalked flowers, and on the axis, just below each apparent leaf-stalk, there is a slight ridge, a leaf-scar. So that the apparent leaf-stalks are branches, and the small blades, true leaves. Compare CASSIA AURICULATA (fig. 5) and INDIGOFERA ENNEAPHYLLA (fig. 9).

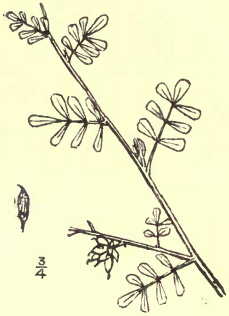

FIG. 9
INDIGOFERA ENNEAPHYLLA

The main stalk (petiole) of a compound leaf is generally called the **rachis,** and a compound leaf is said to be **pinnate** or **pinnately-compound** if the leaflets are borne on either side of the rachis. If they radiate out from the end of the rachis, as in BOMBAX MALABARICUM and HEPTAPLEURUM, they are called **palmate** or **palmately compound** (fig. 10).

Very often the pinnate leaf is still further divided as if it were itself made up of pinnate leaves. We find this, for instance, in CAESALPINIA PULCHERRIMA and in POINCIANA REGIA, the Gold-Mohur. The leaf is then said to be **bipinnate,** and the groups of

leaflets—which look like compound leaves—are termed **pinnas.** These pinnas again may be themselves bipinnate, or still further divided, so that the leaf is

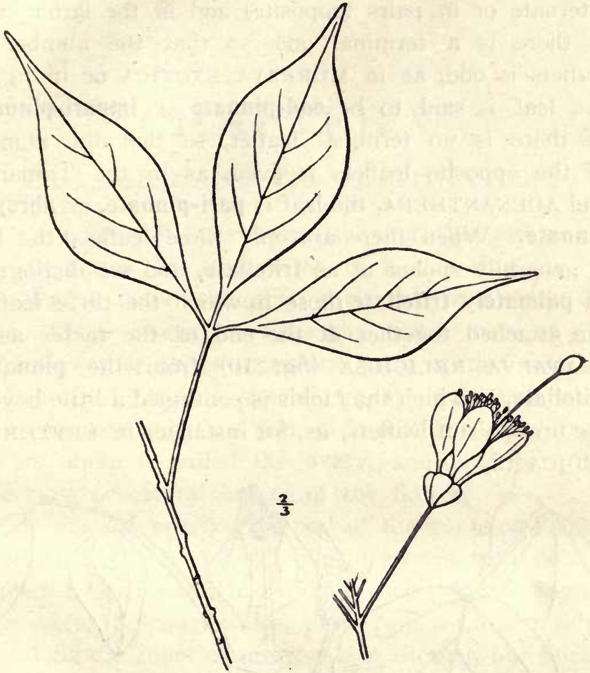

FIG. 10

CRATAEVA RELIGIOSA

trebly or more pinnate, as in MORINGA PTERYGOSPERMA the Horse-radish tree, when it is usually said to be **decompound.** In any case the ultimate undivided segments are called leaflets. Pinnas and leaflets may have small stipules, or **stipels** as they are often called, and they very often have a pulvinus, like the

leaves: but are always distinguished by the absence of axillary buds.

In pinnate leaves or pinnas the leaflets may be alternate or in pairs (opposite) and in the latter case, if there is a terminal one, so that the number of leaflets is odd, as in MURRAYA EXOTICA or in fig. 9, the leaf is said to be **odd-pinnate** or **impari-pinnate.** If there is no terminal leaflet, so that the number of the opposite leaflets is even, as in the Tamarind and ADENANTHERA, the leaf is **pari-pinnate,** or **abruptly pinnate.** When there are only three leaflets the leaf is generally spoken of as **trifoliate,** and we distinguish as **palmately trifoliate** those in which the three leaflets are attached together at the end of the rachis as in CRATAEVA RELIGIOSA (fig. 10) from the **pinnately trifoliate,** in which the rachis is continued a little beyond the first pair of leaflets, as, for instance, in ERYTHRINA INDICA (fig. 9).

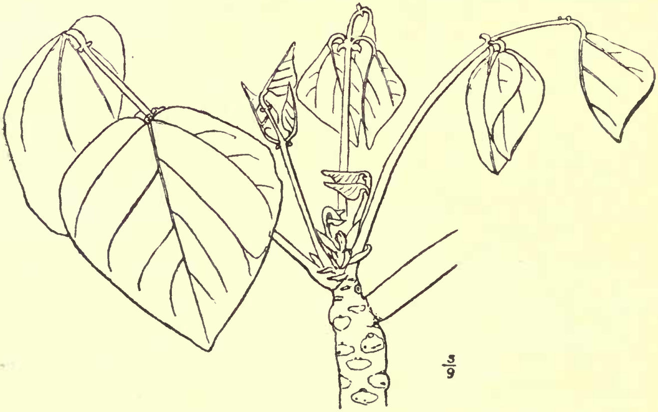

FIG. 11. YOUNG LEAVES OF ERYTHRINA INDICA

CHAPTER V

THE SEED AND ITS GERMINATION

1. So far we have been studying the outlines of the vegetative life and work of plants, but, as we have learnt, there is another work, that of REPRODUCTION, which is just as important, if not more so.

All flowering plants reproduce, in a normal way, by seeds formed inside a special organ which may eventually become a hollow pod, or a soft and juicy fruit.

This organ is called the **ovary,** and is a part, the innermost or central organ, of the flower.

Now take a nearly ripe pod of the common Lablab or of the Pea. In general shape it is a narrow oblong, pointed at each end, and curved at one side. Along the outer edge, the convex side, there runs a narrow ridge, and along the inner or concave side another, but thicker raised ridge which is double. These ridges are called the **sutures.** That on the convex side being the dorsal, that on the concave side the ventral suture. At one end there is a short round stalk which was the stalk of the flower by the development of one part of which the pod has been formed. At the junction of the pod and its stalk is a raised ring which represents the base of the flower, all the rest of which

has fallen off. At the other end the pod narrows into a thin long point which curves in the opposite direction. This is the style of the ovary and is no larger than it was in the flower; at the very tip the style is curved abruptly still more backwards.

If now the pod be opened along the dorsal suture, five or six seeds will be seen attached along the inside of the opposite or ventral suture. Each has a short stalk called the **funicle,** attached to the pod and to a large white growth on the seed called the **hilum.**

In many plants the hilum is not so large as in the Lablab, but is hardly visible at all, its position being then marked by the scar left by the funicle on the seed when the latter falls out of the pod.

At one end of the hilum, the end which was towards the stalk of the Bean-pod, there is a small hole, which can sometimes be seen more clearly after the seed has been soaked in water, for if it be then wiped and squeezed, water will ooze out of this hole. This is called the **micropyle,** and occurs in every seed. The position of the micropyle in relation to the funicle and to the pod is the same in all the seeds of the pod, and of all plants which are akin to the Bean.

On the side opposite to the hilum the skin of the seed appears to be drawn together. This is the **chalaza,** and marks what is really the base of the seed. Between the hilum and the chalaza is a raised ridge barely visible, which is called the **raphe.**

Examine also the seeds of other Beans—the Broad-bean, Brown-bean and Gram, and make out the same parts in them. On the Brown-bean at one end of the hilum, furthest from the micropyle, there is a small

dark triangular area; on the Broad-bean two brown spots in the same place. This is termed an **aril.** It is much larger in some seeds, as the Nutmeg where it extends almost all over the seed in red finger-like processes. In the Korukapuli it extends half over the surface as a yellowish-white body. But it is not a necessary part of any seed, and is altogether absent from those of most plants.

Now take a Castor-seed. It is oval in outline; with a slight ridge down the middle of one side. This ridge is the raphe, and where it ends is the chalaza. At the other end of the seed is a yellowish-white outgrowth called the **caruncle;** this occurs in very few seeds, being peculiar to the Castor and plants allied to it. It surrounds the micropyle, which can be seen as a minute hole at its end. The hilum is almost too small to be visible, but on breaking open a pod that is not quite ripe, we may see that the seeds are attached, one in each chamber of the pod, by short stalks just under the caruncle, so that the raphe runs down from the hilum, as it does in the Bean seeds, and is clearly seen as a slight ridge.

Sow seeds of the Broad-bean, Brown-bean, Gram, Melon or Cucumber, Castor, Date, Onion, Maize, and any other kinds you like, in pots of soft sandy soil and keep them moist, covering them with a plate of glass or wood. All these seeds, except the Maize, have a hilum and micropyle, though these are sometimes very difficult to make out. In the Melon-seed they are close together at one end, and it may not be easy to make out which is which. The Date-seed

has a groove down one side while in the opposite is the hilum. The micropyle is next to it, but hard to see. The Maize-grain—as also all cereal grains, Wheat, Paddy, Cholam—has no micropyle, for the seed is in reality enclosed in its own pod, but too tightly to be separated from it, and the micropyle is hidden inside.

After about a week, sow another lot of seeds. When the first lot has begun to germinate and show above the soil, we may examine them in turn.

2. We will first take the melon-seedlings. The first sign of the young plant is an arched axis which pushes up the soil, and in a day or two comes clear out above it. Pull one of them up.

One arm of the arch is short and is connected with something inside the seed; the other is much larger and has branches going obliquely downwards through the soil—these are the roots.

Now notice that the seed-coat gapes open, and that the lower side is held down by a swelling on the other arm of the arch, just above the topmost root-branch. This swelling is quite peculiar, and is found only in plants of the Melon and Cucumber kind.

In the course of the next day or two the arched axis bends backwards, and literally pulls out of the seed-coat two thick flat oval bodies which very soon turn green. The axis then straightens and becomes upright, in a line with the root, and the two flat green things stand out sideways. Their resemblance to leaves is obvious, they must be leaves. Between them is a tiny bud, and in a few days this grows out as a shoot axis, and bears leaves. When the plant has

grown a bit, we see that the first two leaves are utterly unlike the others. They are, for instance, opposite, while the later and ordinary leaves are alternate. Then again they are attached close to the axis, and have a smooth surface and an even outline, whereas the ordinary leaves have long stalks, and are of quite a different shape, and may be rough to the feel and have a jagged outline. Because these two first leaves are so very different from the ordinary leaves of the plant, they have been given a special name, **cotyledon,** and the part of the axis which is below the cotyledons, and between them and the root proper (which begins at the level of the peculiar swelling referred to), is called the **hypocotyl.**

Now examine seeds that have been a shorter time in water, or in the moist earth. They are larger than when dry, and the seed-coat is burst open at the narrow end (where the micropyle and hilum are). Through the opening there protrudes first a smooth white pointed body. This develops afterwards into the first root, and is called the **radicle,** and you should notice that it always points downwards. In whatever position the seed may be put, whether sideways or flat, or with the micropyle upwards or downwards, the radicle, as soon as it has emerged, turns downwards through the soil.

Now if we split the seed right open, we shall find inside only two white flat bodies, which obviously are what afterwards become the green cotyledons. We may take seeds which have hardly begun to germinate, and still find these two flat white cotyledons, so that the cotyledons and the short bit of

axis that connects them and ends in the radicle are already formed in the seed. Germination only means the greater development of the different parts—cotyledons, radicle, hypocotyl and bud.

This miniature plant that is in the seed is termed an **embryo.** We must not suppose that the whole

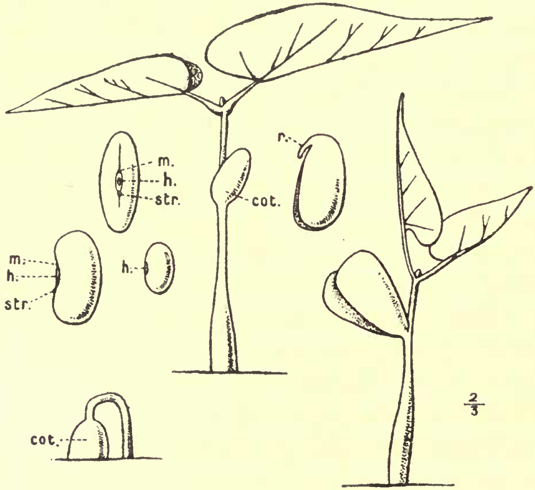

FIG. 12

THE BROWN-BEAN AND ITS GERMINATION. ⅔ NATURAL SIZE

m.	micropyle
h.	hilum
str.	strophiole or aril
cot.	cotyledon

plant is present in the embryo, it is only the cotyledons, and the short piece of axis which connects them and terminates in one direction in the radicle, and in the other in the bud of the shoot. This by the way constitutes another of the differences which

separate plants from animals. The embryo, of at any rate one of the higher animals, expands after birth, while that of a flowering plant remains practically the same size, becoming the mature plant only by the addition of *new* organs.

3. Now look at the pot containing the Gram or the Brown-bean seeds. Here again, the first sign of the new plant is an arched axis which pushes up the soil, and breaking its way through, at length emerges, and as it straightens, pulls up out of the seed two thick flat bodies. Between them is a bud, which soon develops as a shoot axis with two green leaves at the top, each folded along its middle line, and one inside the fold of the other. These being exactly like the later ones are the first normal leaves and correspond to the first rough leaves of the Melon. So that the two thick white bodies correspond to the cotyledons. Indeed, while still in the seed, they are in no essential point different. But those of the Melon turn green, and are thus able to make food for the young plant soon after they have emerged from the ground, while the cotyledons of the Bean are thicker and contain so much ready-made food-material given to them by the mother-plant, that they can, without turning green, supply food at once to the seedling.

It is perhaps because of this that the shoot-bud of the Bean is larger and develops more quickly than does that of the Melon. It would seem indeed, as if there were no necessity for the cotyledons of the Brown-bean or Gram to leave the seed at all, because, being colourless, they can gain nothing from the light and air, and might as well stay underground.

4. With this in our mind let us turn to the seedlings of the Broad-bean and Pea. At first sight the germination appears to be utterly different. There is no arched hypocotyl drawing up two broad or thick cotyledons out of the seed. Instead, the earth is pushed up by a leafy shoot whose first leaves are at once of the ordinary kind, a little simpler perhaps, but not really different from those which come after. Moreover they are not opposite as cotyledons are, but alternate.

If we pull a seedling up we shall find it still attached to its seed, or rather to two thick white bodies which completely fill the seed and which we at once recognize as corresponding to the cotyledons of the Brown-bean or Gram. They are indeed no way different from them, except that they remain inside the seed, and are not drawn up above the ground.

In a very short time after the beginning of germination they become soft and watery and eventually disappear, not because they decay, but because their whole substance is absorbed by the young plant.

And here we see the principle of providing for the seedling by packing food in the cotyledons, followed to perfection. The waste of material and energy in the drawing out of the cotyledons by the hypocotyl as we see it in the Gram and Broad-bean is done away with, and the shoot can begin its life just a little earlier.

Now examine seeds that have been soaked in water a day or two, and become soft. As in the Melon, so in the Brown-bean, Gram, Broad-bean and Pea, there is an embryo consisting of two large cotyledons, which fill practically the whole seed, and are connected with

a short axis, smooth and pointed at one end which is to become the radicle and having at the other end a bud.

The seed coat is folded in between the radicle and the cotyledons, so that there is as it were a separate pocket for it. The bud of the Broad-bean or Pea is easily made out, having two or more leaves which, though small, are clearly visible. Those of the Brown-bean and Gram are not so obvious, for the leaves are not so far developed; and that of the Melon is still more difficult to distinguish.

These differences seem to be connected with the amount of food the cotyledons can supply, and the consequent rapidity with which the young plant can develop.

5. Now look at the Castor seedlings. The first sign of the young plant just as it was in the case of the Brown-bean, Gram and Melon, is an arched hypocotyl which draws after it through the soil two flat cotyledons; these spread out to the light and turn green. Between them is the bud of the shoot, and as the other leaves appear, notice again how different they are in every way, except colour, from the cotyledons. If the seeds have not been buried deeply you will often find on the cotyledons, and at first closing over their ends a slimy yellowish substance, which if left on gradually dries up till scarcely thicker than a piece of paper, and then falls off. As the cotyledons have come out of the seed, this slimy substance must have done so also, and to find out what it is, we must examine the seed.

Unlike the Bean, Gram and Melon, the Castor-seed swells very little in water, the coat being very hard.

But this splits open at the caruncle end, and we can easily remove it. Then we find not an embryo with two white cotyledons as in the Beans, but a white body with a thin papery covering, from one end of which—the micropyle end—there breaks out through it the tip of the radicle. The radicle, we must note, is not a part of the white body, but breaks through it from inside.

Splitting this body open carefully we shall find the embryo inside.

Its cotyledons are very thin, thinner at first than the thinnest paper, but as germination proceeds they become thicker and larger until they may each be four times as long and broad as the seed from which they came out. Their leaf-nature is indicated from the very first, by the lines with which they are marked—exactly as leaves are.

In the seed, therefore, there is something else besides the embryo,—enclosing it. This substance is called the **endosperm,** and it is packed tight with oil and substances of a mineral and proteid nature. In the process of germination the endosperm absorbs water, swells and becomes soft, and the oil and other food substances in it are absorbed by the cotyledons. Thus it is that these, though at first as thin as paper and only quarter inch long, become eventually over an inch in length and comparatively thick, while the endosperm itself becomes soft and slimy and is gradually absorbed till there is left only a skin which finally falls off.

Comparing the Bean and the Castor-seed we see that in both there is food-material stored up for the young plants; but in the Bean it is in the cotyledons

—part of the embryo itself—while in the Castor-seed it is outside the embryo, and must be absorbed by the cotyledons.

6. Now examine the Onion seedling. Here again is a green arch which pushes up through the soil, and coming up above the surface gradually pulls one end out of the seed (to which however it remains attached for some time), while the other end fixes itself in the ground by roots. Then it stands upright—a thin cylindrical green organ, without petiole or blade, but with quite low down on it, a tiny white scale. This scale turns out to be the beginning of a leaf, and other leaves follow, narrow and without difference of stalk and blade, and thereby quite unlike the broad stalked leaves of the other seedlings we have studied, but still in every sense of the word —leaves. They all arise from about the same place, the stem, so far as there is one, appears to begin and end at this spot. It is indeed very short almost entirely absent. What then is the green curved body that came first out of the seed?

Its likeness to the ordinary leaves of the mature Onion plant points to its being of a leaf-nature, and just as in the Castor, the two cotyledons, obviously the first leaves, remain for some time with at least their tips inside the seed coat, and in intimate contact with the endosperm which they gradually absorb, so here in the Onion the first leaf is connected by its tip with the seed and absorbs nourishment from it, and must in the same way be called a cotyledon. But there is this difference, the Onion has only one cotyledon, not two, nor is there in it

any trace of a division, for it is not formed as one might possibly suppose by the coalescence of two leaves, but is just a single one.

7. The Date-seed will take much longer to germinate and when it has done so, the first thing to appear above ground is a thin upright leaf—there is no curved organ like that of the Onion. But look again. This leaf will be found to spring from quite deep down in the soil, and the short stem from which it and the later leaves arise are connected with the seed by a long organ whose tip is in the seed, and can be seen as a wrinkled swollen head inside the endosperm. The latter which at first is very hard has become softer, and just round this head its clear blue colour is changed to an opaque white, which means it is being changed somehow by the action of the head. If the long green organ that connects the Onion plant to its seed is the cotyledon, that of the Date must be a cotyledon too, and in the same way, morphologically speaking, a leaf. The stem and radicle are at first very short and are pushed into the ground by the long growing cotyledon, and from the very short axis, the next few leaves arise.

Before germination has begun it is very difficult to make out any parts in this embryo for the simple reason that the radicle and cotyledon are in one line and the shoot bud is hardly developed at all. But in seeds that have been some time in the earth, the hard bluish-white colour of the endosperm will have changed to a dull white soft substance just near the embryo, and as germination goes on this area of dull white spreads through the endosperm.

Here we see the digestion of the hard endosperm by the cotyledon going on, for this hard white substance is mostly solid cellulose, but from the tip of the cotyledon is secreted a substance which changes it into another kind of carbohydrate—sugar—which being soluble can be absorbed by the plant.

Canna seedlings can more quickly be raised, and in them the structure is very much the same only that the cotyledon is very short, consisting in fact only of a round head inside the seed (absorbing the endosperm exactly as does that of the Date) and a very short stalk outside it. Looking at it by itself one would never call it a leaf—nor even a cotyledon—but the case is after all, not so very different from that of the Pea—only that in the Pea there are two cotyledons and they have already, before the seed was ripe, absorbed the endosperm, a work which in the Canna seed is begun only with the germination.

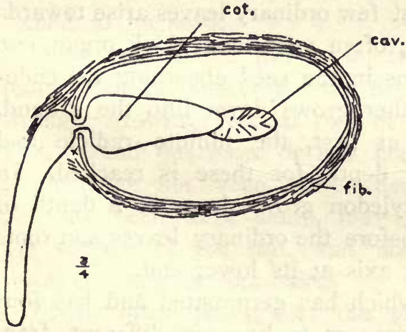

FIG. 13

GERMINATING FRUIT OF THE PALMYRA PALM BORASSUS FLABELLIFER

8. Procure a Palmyra nut that has been planted and has begun to germinate. There is no micropyle visible, for the seed is really enclosed inside the hard outer shell, so the micropyle cannot be seen. The germination is apparently

much the same, but the young plant is very much larger from the first.

A thick club-shaped organ comes out and grows downwards. The tip of this is the radicle, the rest is the cotyledon which lengthens and pushes the radicle deep into the soil. The other end of the cotyledon remains in the seed and bulges out like a ball and here again one may easily see the change in the endosperm as it is digested by the cotyledon. The hard bluish-white changes to dull white as the cellulose is digested and transformed into sugar.

After a while the base of the cotyledon splits open, and allows the next young leaf to grow out. This pierces the soil straight, like the leaves of the Onion and the Date; there is no drawing out of the leaf backwards and spreading it out horizontally as with the Pea and the Broad-bean.

The germination of all Palms follows on much the same lines. The first few ordinary leaves arise towards the lower end of an, often very long, thick organ, one end of which remains in the seed absorbing the endosperm, while the other grows down into the ground, pushing before it, at first, the minute radicle and stem, till the right depth for these is reached. In some palms this cotyledon grows down to a depth of six feet and more, before the ordinary leaves and roots arise from the short axis at its lower end.

Get a Coco-nut which has germinated and has four or five leaves. It appears to be very different from the Date or Palmyra for the leaves come out at the top, and the roots grow out through the fibrous husk. But

cut through the fibre with a saw, and remove it, the roots will then be seen to spring from the same bulbous shoot, *outside* the seed, as the leaves do; and if the shell be broken open there will be found inside a yellow very soft and spongy globular body which almost completely fills the seed, and is connected to the young plant through a small hole in the hard shell.

This is the cotyledon. It is not much like the other cotyledons we have studied, still less is it like a leaf. But by tracing in this way the various forms the cotyledon takes in monocotyledons, we see that this certainly corresponds with the leaf-like cotyledon of the onion, and is therefore morphologically a leaf.

9. Now look at the Maize seedlings. There is first a short tube or sheath which may be only half an inch long. From inside it comes one a little longer, then a narrow green leaf, at first tightly rolled up inside. Pulling a plant up we find it still attached to the grain and closely to it, very much as the Pea plant is attached to its seed.

From just above the grain, two, afterwards more, roots shoot out and unlike the first one and the single strongly growing vertical root of such a plant as the Pea, spread out more or less horizontally, and if the grains have not been buried deep enough, and the pot has been kept damp, may even lie exposed on the surface of the soil, and show very clearly the thick covering of root-hairs.

Break open the grain; the greater part of it is now watery and rotten, but there is a firm white swollen body directly connected with the plant. This body has been called the **scutellum** and in grains,

that have been softened by lying in water this scutellum can be seen lying on one side of the endosperm, and can easily be removed from it.

If we cut it open right down the middle, we shall find inside a bud of tightly-packed leaves at the upper end, that is the broader rounded end of the grain, and at the lower the pointed tip of the radicle. The axis between the two is attached to the scutellum itself, so that the embryo is enclosed inside the scutellum, and the latter appears to be part of it.

In grains that have begun to germinate, that part of the endosperm next the scutellum is not hard and yellow as everywhere else, but is soft and white. It is the same sort of change as we found in the Castor, Date-seed and Palmyra-nut and is due to the digestion of the endosperm by some substance secreted from the scutellum. The change in this case is from starch (with which the endosperm is packed tight, and which being insoluble in water cannot be absorbed by the plant) into soluble sugar. This is, of course, why the grain becomes watery and rotten—its substance is absorbed by the young plant, just as is the endosperm of the Castor, Date and Palmyra by their cotyledons. In the last case the lower part of the cotyledon surrounds the young bud for some time after germination, while the upper part is expanded inside the seed. In the Coco-nut it nearly all remains inside the seed, just as do those of the Pea, and we have something not very different except only in shape from the scutellum of the Maize. We may infer, therefore, that the scutellum is indeed a cotyledon,

quite different in shape from other cotyledons certainly, but like them, the first leaf organ of the embryo.

The cotyledon, we learnt at the beginning of this chapter, is the first leaf of the young plant, and is already formed in the seed. No one would call the scutellum a leaf, but then neither would one at first sight call the two cotyledons of the Broad-bean and the Pea leaves. We argue that they are really leaves, though changed out of all recognition on account of the very different work that they have to perform, because they are situated exactly as are those of the Brown-bean which come out of the seed, and these again exactly as those of the Melon or Castor which are obviously of a leaf nature.

10. We learn from this that the same kind of organ, e.g. a leaf, may be quite different in shape and character in different plants and in different parts of the same plant, because of the different functions it may have to fulfil. So that the shape and structure of an organ depends very largely if not altogether on its functions; and it is only by comparison with similarly situated organs in other plants that we can tell what it really corresponds to. If it were not for the steps connecting the scutellum of the Maize with ordinary cotyledons and leaves, we might well conclude that it was a special organ produced, because it was wanted to obtain nourishment.

We have had one instance of such a specially produced organ, in the curious swelling which arises on the hypocotyl of the seedling Melon and keeps the seed-coat open. But there is nothing connecting

this with any kind of organ, no plant has a leaf in this position, and it does not arise as far as one can see like a root or a branch of the shoot. We may conclude that it is an organ *sui generis*—i.e. of its own kind—specially developed on Melons and similar plants for the purpose of keeping the seed-coat open, though it might be an undeveloped root. This is a very important principle which is of universal application, and which we shall have continually to use in the study of botany. When an organ differs in character from the usual type, because put to a different use, we say that it is **homologous** with the type but a **modified** form. Thus the cotyledons of the Castor and Melon are slightly modified leaves, those of the Brown-bean are more modified, those of the Pea and Broad-bean are still more modified. So also the curved connecting cotyledon of the Onion and Date is a modified leaf or leaf-stalk; and the scutellum of the Maize, Cholam, Paddy, Wheat, Barley, etc., is also homologous with a leaf but a very much modified form.

11. Looking back on what we have studied we learn what germination means—that it is a very interesting and complicated process whereby the embryo in the seed emerges and develops into the young plant. First water makes its way in through the micropyle and causes the kernel inside to swell so that it splits open the seed-coat. Then the embryo begins to grow, the radicle, being nearest the micropyle grows out first, and it is interesting to see that it shows its root-nature from the very beginning by always turning downwards deeper into the ground.

Then the cotyledon or cotyledons swell and, if there is endosperm, absorb it, dissolving it with a special digestive substance secreted by them.

What follows after this depends on the nature of the plant. In some, as the Broad-bean, Pea and Maize, the cotyledon remains in the seed, and is said to be **hypogeal.** In others, Palms and Onions, it comes partly out and pushes the radicle further into the earth; in others again it is drawn up out of the seed by the arched hypocotyl and brought up above the ground, and then it is said to be **epigeal.** If there is endosperm the cotyledons are thin, but if there is not, they are nearly always rather thick—because they contain food material—and then as the young plant grows become thin and wasted. In every case the young plant begins its life on the food stored in the seed by the mother plant. This stored food consists always of large quantities of carbonaceous matter and some nitrogenous and proteid substances. The carbonaceous matter differs in different plants; in some it is a carbohydrate—starch—and seeds with starchy endosperms or cotyledons form valuable articles of food, such as all cereal grains and pulses. In others it is a different kind of carbohydrate, **cellulose,** as in the Date and Palms generally, and is useless as a food for man, but can be eaten by many animals. In others again it is oily in nature, as Castor, Sunflower, Cotton. In a few it is sugar, as in the Sugar-corn, a special variety of Maize.

12. All these substances are highly concentrated food-stuffs, packed in the seed by the mother-plant for the benefit of the next generation. And if we consider the hundreds of thousands of seeds that most plants

produce each season, we shall easily understand that the providing of all this food-stuff must be a great

FIG. 14

AGAVE IN FLOWER

strain on a plant's resources, and that the reproductive work of a plant calls for really great efforts. Many plants indeed die under the strain, all those small ones,

for instance, which spring up, flower, and wither away in the course of one or two seasons (annuals and biennials, pp. 71, 74). And it happens even with quite large plants—such as the AGAVE (fig. 14) which is planted so much as fencing along railway lines: and with even the giant Talipot Palm, one of the largest of all Palms, which may grow on for thirty, fifty, or even a hundred years, and attain a height of a hundred feet, with a stem a couple of feet thick. For when at last a branched flowering axis is shot up and has ripened its hundreds and thousands of seeds, the whole gigantic palm dies, and rapidly decays (multiennials, p. 74).

That with the common AGAVE death is due to the effort of providing for the next generation is recognized in the common practice of cutting down the flowering shoots, whose truncated and bent stems are a familiar sight along our Indian railway lines.

It is for a similar reason that grass cut for hay is much more nutritious just before or at the time of flowering than after the seed has ripened. For the flowering stems are then full of sugar and other food-material passing up from the underground parts to the seed. Later on they are little more than woody stalks, and the seeds which contain the food-material soon drop off and are lost.

For the same reason the worst time for moving bulbs and tubers is just at flowering time. or after, for they are then at their weakest, having given up their sugar or other food substance to feed the seeds.

13. Reviewing all these plants whose germination we have been studying, we see that they fall naturally

into two groups, those which have one cotyledon and those which have two. And the plants of these two groups differ in many other respects too, for, when full-grown, Beans, Melons and Castors have a well-branched shoot and broad flat leaves with veins that branch in all directions, and leaf-stalks which stand out more or less at right angles to the axis, so that the blades face the light. The stems of Paddy and Wheat or Maize on the other hand are not branched, except quite close to the ground, and their leaves are long and narrow, with parallel veins and no petioles. The Onion has no stem at all above ground, except for the flowers, all the leaves springing directly from the short bulbous stem. The Coco-nut and Palmyra and palms in general certainly have a stem, but this practically never branches, and their large flat leaves are not a bit like those of our ordinary trees.

We see then that the difference in the cotyledons accompanies differences of the shoot and leaves and in fact in the general character of the mature plants; and for this reason all ordinary flowering plants have been divided into two great classes distinguished as **monocotyledons** and **dicotyledons.**

I. The DICOTYLEDONS have two cotyledons, and include all our trees (other than Palms), ordinary shrubs (but not Bamboos) and nearly all broad-leaved flowering plants, except Caladiums, Arums, and Yams (DIOSCOREA).

II. The MONOCOTYLEDONS have but one cotyledon, and include all our cereal plants (Maize, Paddy, Wheat, Cholam and Grasses), in all of which, the cotyledon is specially modified as the scutellum, Lilies,

FIG. 15

A FIR

MONOPODIAL GROWTH AND VERY REGULAR BRANCHING

CRINUM, Onion and nearly all bulbous and narrow-leaved plants together with the Palms, and a few with broad leaves, as the Yams and Arums.

There is, as a matter of fact, a third group of quasi-flowering plants, with which however we are not concerned in this book. Their seeds are borne on the outside of special scales, not inside a pod, and for this reason they are known as GYMNOSPERMS. On the plains of India there are very few examples of this group, the common Cycad (CYCAS CIRCINALIS) being about the only one; on the hills there are a few others, but for the most part planted by Europeans, and not wild, such as the Pines and Firs (fig. 15). In colder climates this group is of much greater importance than it is with us.

CHAPTER VI

THE DIFFERENT TYPES OF PLANTS

THE functions which we studied in chapter iii are concerned directly with the life of the plant itself, and are termed vegetative functions. But we learnt that there is another work that a plant—together with every kind of living thing—must do, and that is to reproduce its own kind. The ordinary mode of reproduction is by seeds, and these are produced only in the flowers. So that while the roots and leaves are concerned with the vegetative functions, the reproductive functions belong properly to the flowers.

The proper performance of the vegetative functions benefits the individual plant itself: the more water and mineral salts the roots can absorb, the more light and air the leaves can obtain, the more food-material will be made and the larger and stronger will the plant become, so that it will be the less likely to be damaged by grazing animals or hurt by the hot, dry winds of summer. The production and scattering of the seeds are of no benefit whatever to the plant itself—they are on the contrary a tax, for the more seeds are

produced the more of its substance is scattered and lost to the individual.

It is on the other hand the race as a whole which is benefited, for obviously the larger the number of seeds, and the stronger the young plants produced each year, the more rapidly will the race increase in numbers and spread over new land.

We must think, therefore, of every plant as being engaged in two great kinds of work. One, to make itself as strong as possible, and protect itself from any injury, and the other to produce as many and as healthy new plants as possible, to carry on the next generation.

These two functions are to a great extent antagonistic; for instance, it requires time for a tree to grow large, so that its leaves are well out of reach of every grazing animal and its roots deep enough down to get water even in hot weather. And while it is merely growing, a smaller plant may have matured and shed thousands of seeds, which growing up quickly multiply again in their turn, and thus that race of plants may become far more numerous and more widely spread than that of the tree.

Every plant then in striving to carry on these two works to the best of its power under the peculiar circumstances in which it is placed, has to make some sort of compromise between them—and thus it is that we get so many different kinds and sizes of plants.

Some take only a few weeks or a month to grow up from seed, produce flowers and scatter their seeds. Plants which do this between one growing season and the next are termed **annuals.** Naturally they have

no time to make strong woody shoots and are almost always small plants, such as the ordinary food grains, Paddy, Cholam, Wheat, and Barley, Tobacco and the many flowering annuals, that are sown every cold season in our gardens.

Others live on for many years and produce seeds every year, though usually not in their first season. These are termed **perennials.**

There are several kinds of perennial plants. First are those which have a thick main axis (stem) and a crown of large leaves. This is the **Palm type**—too well known in the tropics to need description. Not only Palms but Cycads and Tree-ferns are of this character.

Then there are what we ordinarily call **trees**—woody plants with a thick stem that divides or branches at a certain height above the ground, and bear a very great number of much smaller leaves —such as the Mango, Banyan, and Teak.

Those which have no main stem, but several woody stems springing from the ground, like the Bamboo, Ixora, Pomegranate, Rose are termed **shrubs.** In some of these the stems are weak, and support themselves by straggling over other plants, as ZIZYPHUS, LANTANA, RUBUS. These pass gradually into the fourth group of plants, which like the Vine, BOUGAINVILLÆA BAUHINIA, THUNBERGIA, the Pea and others climb up the trunks of trees, or the surface of rocks, supporting themselves by thorns, clinging roots or special clasping organs called **tendrils.** This we may call the vine or **liane** or **climbing** group.

A fifth group of perennial plants consists of those which have no woody parts, but are on the contrary

very soft and juicy, like the Prickly-pear. These are termed **succulents,** and usually have green stems and no leaves, like OPUNTIA the Prickly-pear, or if there are leaves they are very thick and fleshy, as in BRYOPHYLLUM and KALANCHOE.

Then there is a sixth group, which have a soft green leafy part above ground, that dies down like an annual each year, while the part below in the ground lives on. Common instances of this are the Ginger plant, Canna and Lily. These are **perennial herbs.**

Of these six groups, all except the last live on practically unchanged through the year, being able to stand the heat and dryness of summer in the tropics, or the cold of winter in the cooler parts of the world, either because all the parts above ground except the leaves are hard and **woody** (as in the Palms, Trees and Shrubs), or because they contain quantities of water stored up in their tissues (as the succulents), this water being used up gradually during the hot months, or because they drop their leaves in the dry season.

Look at a Prickly-pear, and see how soft and watery it is at the end of the wet season; and look at it again after the dry months and see how thin and shrunken it looks. The difference in appearance is entirely due to the loss of the stored up water which has taken place during the dry months.

The sixth group has no woody or succulent parts, but the perennial part, being underground, is not likely to become too dry. This usually contains a good deal of food material with which to build the new shoot at the beginning of each year, and for this reason is

often a very useful article of food, as the COLOCASIA and ONION.

In colder countries where there is much more difference between the seasons, and where during one part of the year active life ceases, not because of dryness but because of the cold which prevents roots taking up water, there are plants which live only two years, and spend the first season in purely vegetative work, making large quantities of food and storing it for use during the second season, which is devoted to the production of flower-seeds, that is, to reproductive work. These are termed **biennials,** and most of them have rather thick underground parts in which food-material made during the first season is stored for making the seeds the second year. For this reason many of them, like the sixth group of perennials, are valuable food plants, and some, as the Carrot, Radish, Turnip, are grown in this country.

Then again there are those referred to in the last chapter (section 12) which live for many years, but flower only once and die soon after the seeds have fallen. These may be called **multiennials.** They have mostly stems of a palm nature, as the Talipot-palm (CORYPHA), or the so-called Aloe (AGAVE).

Looking at plants from the point of view of the length of their lives, we class them as annuals, biennials, multiennials and perennials; looking at them from the point of view of their nature and substance, we may classify them as:—

(1) **herbaceous**, when they are soft and *not* woody, for example, the ordinary field and garden annuals and some perennials.

(2) **succulent**, when they contain much water, and
(3) **woody**, when hard like shrubs and trees, Palms, and most vines.

It must not, however, be supposed that these classes are divided sharply one from another. It is sometimes difficult to know whether to call a plant a small tree or a shrub; and in hot countries like India, herbs will often become woody towards the beginning of the hot weather.

But generally speaking herbs are small plants, less than the height of a man. MUSA, the common Plantain or Banana, is larger, but it is by far the largest of all herbs. Shrubs seldom run up above twenty feet, only some very large Bamboos attaining the height of an ordinary tree.

CHAPTER VII

GROWTH

1. The study of the mode of growth of plants is so closely dependent on that of their internal structure (another branch of Botany called HISTOLOGY with which this book does not deal), that we cannot go fully into it; but there are a few main facts that can be made out without much difficulty.

If you watch from day to day the ends of the branches of any tree or bush that is putting out new leaves, you will see that they increase in length by the growth of the internodes of the bud, new pieces being literally added on in this way one after the other. To prove that this is the only way in which a branch increases in length and that the other parts do not themselves become longer, we have only to take any quickly growing branch or stem and mark on it thin black lines with India ink at equal distances, say one-eighth inch apart. In a day or two those on the youngest internode will be much further apart, showing that it has really lengthened as a whole. The next internode may also show slight signs of growth, but after two or three days the marks remain exactly the

same distance apart, and will do so however long the observations are continued. There are some trees (see section 3) on the surface of which the leaf-scars persist for many years, and we may, by direct comparison of the old stems and young branches, see that the leaf-scars are on the whole the same distance apart, and therefore that there has been no longitudinal growth.

This is an observation which you should not fail to make for it is quite easy, and it is a clear proof of a very important principle that a tree does not grow, as is sometimes supposed, by a general lengthening of the trunk and branches, nor by being pushed up out of the ground from the roots, but only by the addition of new pieces to the ends of the stem and branches above. So that if a branch meets the stem at a height, say of ten feet from the ground one year, it will be at the same level the next year, and the next, and for a hundred years if it lasts so long. It is only the height of a tree as a whole that increases each year, and it does so as a rule till death or accident puts a stop to further growth.

This mode of growth constitutes an important point of difference between animals and plants, for animals grow by enlargement of every part and organ, not by addition to the ends of the trunk and limbs.

2. Again, the branch or stem of an ordinary tree consists of a hard woody core surrounded by a tough bark, which is soft or hard and stringy on its inside, and often rough and broken towards the exterior. These two parts, the woody core and the surrounding bark are entirely different in nature. Wood never turns into bark, nor does bark turn into wood; and

they can be readily separated when in active growth because between them is a very thin layer of delicate tissue which is easily ruptured.

This layer is called the **cambium,** and by its growth and development woody tissue is added to the core, and soft or stringy fibrous tissue to the bark. So that the core grows centrifugally by the addition of new layers of wood to the outside, and the bark centripetally by new layers on its inner side.

Now it is only through small tubes in the youngest parts of the wood and the bark that sap passes up from the roots and down from the leaves, the middle of the core being useless for this purpose.

At the beginning of the hot weather, when the buds are opening out and growth is rapid, the new tubes of wood that are formed are larger than later on in the year when growth is slower; and by the regular alternation of the wet and dry seasons year after year, there are formed alternating zones of more and of less compact and hard tissue. This is why, when the trunk or branch of a tree is cut across, a number of concentric rings can generally be seen. In countries where the difference between the seasons is more marked than in the tropics, these rings are always very distinct and show by their number the exact age of the part; for each ring corresponds to a winter or a summer, and indicates one year's growth.

This is also the cause of the 'grain' of timber—those lines and markings which can be seen on nearly all wood. By feeling with a knife one can at once tell which are the hard winter or dry weather and late

summer layers, and which the softer spring or wet weather growths.

This growth in thickness by means of the cambium layer takes place only in dicotyledons. Monocotyledons do not increase at all (except in one or two genera and then by a different method) for they have no cambium, and in consequence also no bark. Compare, for instance, a Palm with a Rain-tree (PITHECOLOBIUM SAMAN), or Indian Cork (MILLINGTONIA), or any ordinary tree. The latter have a bark that can be easily stripped off the younger branches, but there is none on the Palm, its substance is of the same nature right through, though harder towards the circumference being merely covered on the outside by the bases of the leaves that have fallen.

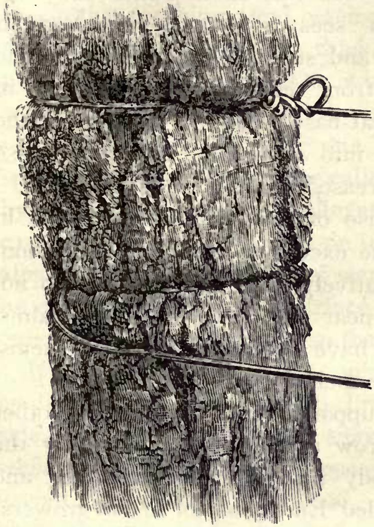

FIG. 16

TRUNK OF A TREE, ACACIA MELANOXYLON, WHICH HAS BEEN USED AS A POST FOR TYING THE WIRE OF A RAILING

To show how such a tree grows in thickness at or near the surface, not by expansion from the middle.

The wire has not bitten into the tree, but the tree has grown round the wire.

Now one may often see a plant twining round the stem of a tree, and looking as if it had cut into the bark. This is because the tree has gone on growing in thickness except where actually prevented by the coils. But you never see this on a Palm. For instance one sometimes sees a FICUS or Banyan growing on a Palmyra and sending its roots round the stem, having started from seed left by some bird in he axil of an old leaf-base. But it never has the appearance of cutting into the palm, simply because the latter has not increased at all in thickness.

It is probably because of their inability to grow in thickness that, with the exception of Palms, all monocotyledons are comparatively small plants, and do not have branches except near the ground. Even Palms, tall as they may be, have comparatively thin stems, and are very rarely branched.

Formerly it was supposed that Palms and other monocotyledons did grow a little in thickness by the addition of new woody matter inside the old, and they were therefore called Endogens (or inside growers) while dicotyledons were called Exogens (outside growers). These names, though still used by some people, and in old botany books, have now no scientific value.

Dicotyledons on the other hand may attain almost any thickness. There used to be a Chestnut-tree on Mount Etna, 180 feet in circumference; and BOMBAX MALABARICUM, the silk-cotton tree, has been known to attain an even greater thickness, and another very thick tree the Baobab (ADANSONIA DIGITATA) is often found in gardens, with trunks ten feet or more thick.

All these started life as seedling plants, thinner than a lead-pencil.

3. Now consider bark more closely. On some trees, as species of FICUS (Banyan, Peepul, etc.), the bark is smooth, and being thin, quite a small cut will reach the cambium and young wood layers. But in most trees the bark is thick, and cracked on the outside, and if one cuts it with a knife there is no water or sap: it is quite dry and dead. The drying up of the outer parts is due to the formation of a special waterproof substance called **cork.** This is formed by a layer called the **phellogen** which grows like the cambium but produces cork on its outside. Cork, being almost impervious to air and water, prevents loss of sap by evaporation from the surface, and it also cuts off the outer tissues from the sap, so that they dry up and die.

If the phellogen occurs only just underneath the epidermis and forms but little cork on its outer side, the bark may remain smooth, as in FICUS. But when, as more usually happens the phellogen occurs deeper in, nearer the wood, there is much more bark tissue outside it. And since this bark, being dead, cannot grow or expand as the tree increases in thickness, the pressure of the growing wood from within causes it to split open in longitudinal cracks.

This is the cause of the familiar rough appearance of bark; and different kinds of trees differ in the roughness of their bark according to the difference in the depth of the phellogen below the surface and the amount of bark which is formed.

In some trees, e.g. MILLINGTONIA (the Indian cork-tree) and in the ordinary Spanish Cork-Oak, the

cork, in the course of a few years, may become two or three inches thick, or even more, and it can then be cut off, and made into corks for bottles, etc.

Just as layers of hard and of softer wood are formed in different seasons of the year, so, too, layers of hard and soft tissue are formed in the cork. These can nearly always be seen in any bottle-cork—the softer broader part is formed in the spring months, March, April, May, and the other later on in the year.

It is the waterproof and yielding, yet firm nature of cork, that renders it so useful for keeping liquids in bottles, etc.; and it is precisely those same characteristics that make it so useful to the tree. For it prevents loss of sap by evaporation from the surface of the tree, and the dead tissue outside offers no attraction to animals to nibble at the trunks. In FICUS (Banyan, Peepul, etc.) and some other trees the cork and bark are very thin and can easily be bitten through; but the sticky and poisonous milky juice contained in these trees prevents animals to a certain extent from doing much damage.

Again in many trees a second layer of phellogen is formed deeper in the wood, and by forming cork cuts off the sap from the original phellogen, which therefore dies. When this happens the outer part, from the first layer of phellogen outwards, generally comes off, it may be in flakes as in STEPHIGYNE, PINUS (Pine) and PLATANUS, the Plane-tree, or in long pieces as in the EUCALYPTUS, or in almost complete cylinders as in the Cherry-tree and Birch.

On the young branches of very many shrubs and trees there are often to be seen little brown or

yellowish pustules or openings in the outer skin. These are called **lenticels** and consist of very loosely arranged tissue, through which air and water-vapour can pass in or out. They are formed underneath the stomas when, owing to the formation of cork the latter are cut off, and die along with the epidermis; and to a certain extent they take their place, allowing the carbon-dioxide respired by the living tissues close by to escape. But they differ from stomas in that they do not open and shut, and therefore do not in any way control the amount of air and water-vapour passing through.

Later on, when the bark is more fully formed and its outer layers become dry and peel off, the lenticels of course are destroyed too, and there appear to be then no regular passages for the interchange of air. In a few trees the epidermis persists for a long time and when the bark is formed it is thin and does not fall away. In consequence the leaf-scars remain visible even when the branch or trunk is a foot thick.

This occurs in FICUS RELIGIOSA, the Peepul, ACACIA MELANOXYLON, the Black wattle, PLUMERIA ACUTIFOLIA, the Pagoda tree, INGA DULCE, the Korukapuli, and others. We can see the leaf-scars on quite old trunks or branches, extending, it may be, six inches or even a couple of feet in length across the surface. This is because the outer layers have not died but have lived and grown with the growth of the part, and so the scar has extended with them. It is instructive to note that while leaf-scars and bud-scars are pulled out sideways by the natural stretching of the bark as the trunk or branch grows in thickness, as stated above,

no change takes place in their vertical distance one from another on any of these trees.

4. Cork is formed not only in the bark of trees and shrubs, but also across the stalks of the leaves, at the base where they join on to the branch. When it has formed completely across, the leaf necessarily dies and falls, breaking off at the corky layer. So that the wound or scar so made is covered at once by the cork, and loss of water from the exposed surface is prevented. This is why leaves fall off so cleanly with their stalks, and do not leave a ragged broken stem.

Palms, on the other hand, do not form cork (just as they do not increase in thickness) and so when the leaf dies it breaks and leaves a ragged, untidy leaf-base still on the stem. It is only later on that the leaf-base becomes detached and leaves the stem clean.

Cork is also formed wherever soft living tissue is exposed by a wound. If a leaf be cut a thin brown layer forms and prevents loss of water from the cut surface. The same happens with fruits and tubers. If a potato is cut, cork forms over the cut surface; and if it be pricked with a needle a cylindrical layer forms round the wound and prevents loss of water.

The great difference that even a very thin layer of cork makes can be seen very easily in this way. Take two young potatoes, the smaller the better, as nearly as possible the same size. Weigh them, and weigh again in a day or two. Provided that the skin is unbroken very little difference will be found in their weights. But remove the skin from one; weigh it, and

weigh both again the next day, and the next. The peeled potato loses weight at once, and will shrink very much in size.

In an experiment made in this way the two potatoes each weighed $\frac{3}{4}$ tola. One was peeled, and in two days (in a cool place) it had lost $\frac{1}{4}$ tola; and in another two days had decreased by yet another $\frac{1}{4}$ tola; while the difference in the other was hardly visible. Three days later the peeled potato weighed scarcely an eighth of a tola and had shrunk to less than a quarter of its original size, while the other was hardly, if at all, different.

5. By the formation of cork and bark from the cambium, plants are able to heal over wounds caused by the breaking of branches by wind or animals. Thus it is that neat rounded lumps grow where branches have been cut off close to the stem. But if a portion of the branch is left, so that the exposed surface is not close enough to the main axis to be well supplied with sap, the phellogen gets dry and dies, and very soon the core of the branch, exposed as it is to rain and attacks of insects and fungi, becomes rotten and hollow. In time the rot may extend into the trunk of the tree till at last the whole is destroyed, or the weakened trunk breaks across in a high wind. Many a tree has died for no other reason than that a branch had been broken off carelessly, so that the phellogen could not form and cover the wound, instead of being cut off as close as possible to the stem to allow the natural healing to take place.

6. In section 2 we learnt that one great difference between monocotyledons and dicotyledons is that the

stem (and the roots too) of the former do not increase in thickness, and have no true bark as in the latter. But we can easily learn more than this. If we examine the stem of any small monocotyledon, e.g. Cholam, Wheat, Paddy or a Lily, more closely, we find that it is composed of numerous strands of fairly tough material imbedded in a much softer ground-tissue, which can easily be torn apart with the fingers to separate the strands. This is quite different from the stem of a dicotyledon, where (except in a very few cases) there is a solid cylinder of wood. These strands run into the leaves and there form the veins. Those nearer the surface are closer together, and form a hard casing, but not a true bark. These strands are called **vascular bundles** and are composed of six main kinds of elements :—

(1) Continuous tubes with fairly thick walls, in which there are thinner places (pits, not holes). These are called **vessels,** and it is through them mainly that water passes up from the roots to the leaves.

(2) Shorter closed tubes with pointed ends and much the same kind of walls. These are called **tracheids,** and share in the conduction of water up the plant.

(3) Long thin elements, like tracheids, but with excessively thick walls so that there is little or no space inside; these are **fibres,** and their function is to add strength to the vascular bundle, and the plant generally. They usually form a sheath round the bundle and in old decaying stems of Palms one can see the black fibrous sheaths, often after the insides have decayed away. Individually the fibres are really short (seldom more than one-eighth inch) but they often form strong strands

which are of great use, e.g. those in the leaves of the AGAVE make 'Aloe-fibre'.

(4) Long soft tubes, not continuous, but connected end to end through small holes in the terminal walls, which look like the holes in the rose of a watering can or a sieve. For this reason these are called **sieve-tubes**, and it is along them that the food-stuffs manufactured in the leaves, pass to the other parts of the shoot and roots.

(5) Narrower closed tubes of the same length, with pointed ends. They accompany the sieve-tubes and are therefore called **companion-cells.**

(6) Short elements, more or less cubical in shape, like the material of the ground-tissue between the bundles, and called **parenchyma.**

The vessels, tracheids, fibres, and some of the parenchyma are made of the specially hardened kind of cellulose, we call wood; the sieve-tubes, companion-cells and most of the parenchyma, of unaltered cellulose.

These six main classes of elements, individually too small as a rule to be seen except through a microscope, make up the vascular bundle, the sieve-tubes and companion-cells, collectively called the **phloem**, being always on the side nearer the outer surface of the stem, or the lower of the leaf, the vessels and tracheids on the inner, or the upper side in the case of a leaf.

Separate bundles can also be seen in a very few dicotyledons, e.g. the Pepper, and ARISTOLOCHIA (in the latter the vessels are so large that they can be easily made out with the naked eye), and as a matter of fact in all when quite young. But not in older stems and roots, for in a very short time, generally before

the plant is a month old, the vessels and tracheids are separated from the sieve-tubes and companion-cells (phloëm) by the cambium, which forming as we have learnt, fresh wood (vessels, tracheids, fibres and some parenchyma), on its inside, and fresh phloëm (sieve-tubes and companion-cells), with some fibre and parenchyma, on its outer, makes the hard central cylinder of wood, and the outer covering of bark. Thus we see that there is a fundamental difference in structure between the stem or root of a monocotyledon and that of a dicotyledon. The former is composed mainly of vascular bundles which have run down from the leaves, those from the higher ones joining others lower down, the latter of a **secondary** tissue, the cambium-formed woody cylinder and bark, to which the leaf bundles are attached, the wood to the wood, the phloëm to the phloëm.

CHAPTER VIII

BRANCHING

1. We learnt in chapter ii that branches of the shoot arise by development of buds, which are as a rule in the axils of leaves, so that their arrangement depends in the first instance on that of the leaves. But even in a young seedling plant only a few of the buds grow out into branches, there would indeed hardly be room for them all to develop. As the plant grows older and taller, the lower leaves and branches are shaded by the upper, and being as we learnt in chapter iii dependent on light to enable them to get food from the air, are starved and very soon die and drop off. If the plant grows to become a tree, hundreds of little twigs and leaves are thus killed off from the lower parts and hundreds of buds never develop at all, and so it comes about that the stem is not branched close to the ground, and neither it nor the larger branches have leaves.

Only towards the outside where there is plenty of light and air, do we find small twigs and leaves. This is well seen in PITHECOLOBIUM SAMAN, the Rain tree, which is so frequently planted by the

roadside. A young tree has branches and leaves close to the ground. The branches of an old tree are entirely destitute of leaves except at their ends, and there is thus formed a hollow crown of foliage supported by the branches, like an umbrella by its frame. The same is true of the Banyan, Mango and indeed all trees, though in some the outer leaves make so little shade that a few others can grow on the inner branches as well (see fig. 20, p. 102).

But, besides all this, many kinds of trees have their own peculiar shape by which they can be recognized even at a distance. This is due to, among other things, the angle at which the branches leave the main axis. In PITHECOLOBIUM, the Rain tree, they slope steeply upwards, at an angle of about 50° to the vertical. The secondary branches leave them again on the lower side at a similar angle, and there is thus formed a regular hemispherical crown.

The large branches of CASUARINA again are much more upright, while the small ones bring their bend down again, giving to the tree its peculiar drooping graceful appearance. Those of the Banyan grow almost horizontally, and when supported by their pillar-roots, spread very widely.

But the shape depends also very much on the tree's immediate surroundings. If it is in the open, and not shaded by other trees or by buildings, it grows freely and to its natural shape. But when it is with other trees, the shape may be quite different. Branches that are shaded and cannot get sufficient light, are on that account robbed of their due supply of sap by the more favoured shoots and therefore wither and fall off, while

the main stem grows taller and thinner. For this reason when trees are planted for the sake of their timber, they are put fairly close together. The stem then grows very straight upwards, and there being no large branches the 'grain' of the wood is straight and free of knots. But if the tree is grown for the sake of its fruit, it must have plenty of room to branch sideways, and not be made to suffer from overcrowding. A tree that is on the edge of a wood, with one side shaded by other trees and the other in the open air, grows outward all the more widely, because on the side towards the other tree its branches die off, and there is then more sap for the others. It becomes therefore very much one-sided.

It is for this reason that trees grown for shade by a roadside should be fairly close together. They then do not grow much towards each other, and more water and sap is available for the branches that grow across the road, and these therefore grow the more quickly.

2. When we come to look at the branching more closely and in detail, we find there considerable differences in the way in which the smaller branches arise. When the leaves are alternate, the branches are naturally alternate too, and when they are opposite, one would expect to find the branches also opposite. Modifications of these two fundamental arrangements are however caused by the development of some and suppression of other buds.

The simplest arrangement is when the main axis continues to grow more strongly than any of the side branches, these latter arising occasionally, and being

alternate, opposite, or whorled, as are the leaves. Growth of this kind is termed **monopodial,** or **a monopodium** and is the usual arrangement in herbs and young trees.

In Pines and Firs the branching is always of this type, the terminal bud, unless destroyed by accident, continuing to grow strongly throughout the life of the tree. The branches are whorled and arise from leaf-axils near the growing end, and so are progressively older and longer from the top to the ground. The whole tree is in consequence very regular in shape, and has the appearance of a cone (fig. 15, p. 69).

But in most of our ordinary trees the terminal bud of the main stem or branch dies at the end of the growing reason, or gives rise to flowers, so that the lengthening of the axis in that direction is stopped. Growth is then continued by a lateral branch stretching out on one side, or, if the leaves are opposite, by two branches, so that the original axis appears to be divided into two.

In either case the direction of growth is now no longer the same, and it is for this reason that our ordinary trees spread out horizontally and have a more or less rounded appearance so very different from the sharp conical shape of the Fir.

The third type of branching is a further development of the second. The terminal bud dies regularly after one or two leaves have been formed, and its place is taken by the lateral bud standing nearest to it. This becomes a branch, which, pushing aside the now dead terminal bud, continues growing in the original direction.

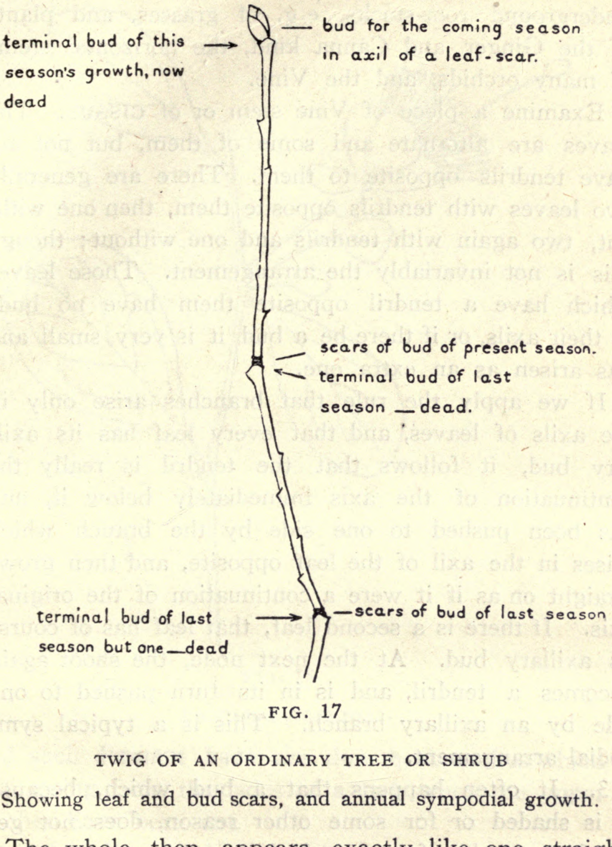

FIG. 17

TWIG OF AN ORDINARY TREE OR SHRUB

Showing leaf and bud scars, and annual sympodial growth.

The whole then appears exactly like one straight axis, but the presence of a leaf-scar on one side without its axillary bud, and of a dead bud on the other side without any subtending leaf, show what it is. This method of growth is called **sympodial,** and the resulting axis **a sympodium.** It is very common in

underground root-stocks, e.g. of grasses, and plants of the Ginger and Canna kind, the horizontal stems of many orchids, and the Vine.

Examine a piece of Vine stem or of CISSUS. The leaves are alternate and some of them, but not all, have tendrils opposite to them. There are generally two leaves with tendrils opposite them, then one without, two again with tendrils and one without; though this is not invariably the arrangement. Those leaves which have a tendril opposite them have no buds in their axils, or if there be a bud it is very small and has arisen as an extra one.

If we apply the rule that branches arise only in the axils of leaves, and that every leaf has its axillary bud, it follows that the tendril is really the continuation of the axis immediately below it, and has been pushed to one side by the branch which arises in the axil of the leaf opposite, and then grows straight on as if it were a continuation of the original axis. If there is a second leaf, that leaf has of course its axillary bud. At the next node, the shoot again becomes a tendril, and is in its turn pushed to one side by an axillary branch. This is a typical sympodial arrangement.

3. It often happens that a bud which, because it is shaded or for some other reason, does not get its due supply of sap and does not grow out into a branch, yet remains alive, and may develop after many years if stimulated to do so by the destruction of other branches. It grows slowly, so as to remain at the surface of the axis as it increases in thickness.

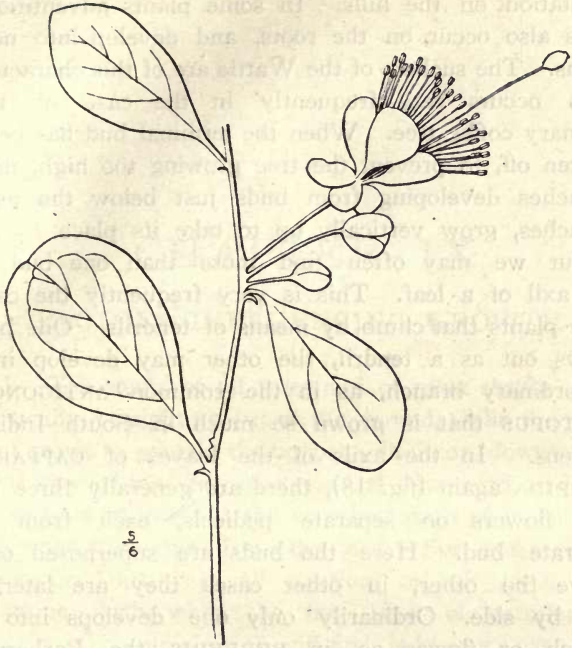

FIG. 18

CAPPARIS HORRIDA

To such **dormant buds** are due the branches which often spring from the sides of a tree when the upper branches have been cut.

Again totally new branches will often arise from the exposed end of a tree-stump that has been cut down. They are formed *de novo* from the growing tissue, and are termed **adventitious buds.** The Neem and Divi-divi trees sprout out very readily in this way, so does the EUCALYPTUS as can be seen in any

plantation on the hills. In some plants adventitious buds also occur on the roots, and develop into new stems. The suckers of the Wattle are of this character. This occurs very frequently in the case of the ordinary coffee tree. When the terminal bud has been broken off, to prevent the tree growing too high, new branches developing from buds just below the next branches, grow vertically up to take its place.

But we may often find more than one bud in the axil of a leaf. This is very frequently the case with plants that climb by means of tendrils. One bud grows out as a tendril, the other may develop into an ordinary branch, as in the common ANTIGONON LEPTOPUS that is grown so much in South Indian gardens. In the axils of the leaves of CAPPARIS HORRIDA again (fig. 18), there are generally three or four flowers on separate pedicels, each from a separate bud. Here the buds are superposed one above the other, in other cases they are lateral, side by side. Ordinarily only one develops into a branch or flower as in BERBERIS the Barberry, where there are three buds, while in ZANTHOXYLUM there may be as many as eight or nine buds in each leaf axil. These extra or **accessory** buds may at first sight appear to be superfluous, but their use is that when a normal branch is destroyed by accident or by being eaten by animals, there may be another branch developing from one of the other buds to take its place.

CHAPTER IX

FACTORS INFLUENCING GROWTH

1. The stems of all trees and of most shrubs grow vertically, straight up out of the ground, while the main root grows in exactly the opposite direction, downwards. This upward tendency of stems and downward tendency of roots is apparent at the very beginning of the plant's life when it emerges from the seed. For, put seeds of Bean or Marrow in all positions in soft earth, and examine them when the first signs of germination appear. The radicle, you will find, is in every case bent downward, and the shoot, though it may be curved at first while passing through the earth, stands straight upright when it is free.

And again take seeds which have begun to germinate and have half an inch or so of radicle exposed, and put them in various positions, covering them with light soil or moss or sawdust; then look at them again after a couple of days. You will find that in every case the end of the radicle is bent downwards, and the shoot upwards.

We may see the same thing in older plants of all kinds. The Palmyra-Date and Coco-nut palms are

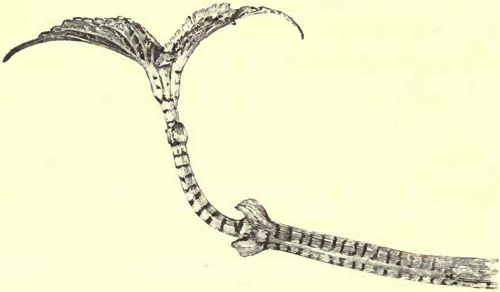

FIG. 19

PHOTOGRAPHED AFTER 12 HOURS

Growing end of a COLEUS after it has been fixed horizontally and marked to show the region of growth.

constantly to be met with, curving at the base for some reason or other, but growing straight up afterwards. Branches of trees and shrubs that have been forcibly bent down or half broken often bend up at their ends.

Observe that it is only the ends which turn up; and actual proof of this fact can be shown quite easily. Take a quickly-growing annual plant, almost any one will do, so long as it is one which naturally grows upwards; cut the leaves off, and with India ink mark, on the internodes at the tip of the shoot, fine lines at equal distances apart, say $\frac{1}{8}$ in. or $\frac{1}{4}$ in., according to the size of the plant. Then place it horizontally against a piece of board, on which you may mark its position, either keeping it in its pot, or with its end in a corked tube of water to keep it alive. Cover it with something to keep off any light, and prevent

its being touched, and leave for the night. By morning the end will have turned upwards, and you will find by looking at the marks that it is only the youngest parts, those internodes which are still in the process of lengthening, that bend; the older parts that have finished growth do not move.

If you have another plant treated in the same way but standing vertically, you will find that the lines on the lower side of the curved end of the horizontal plant are further apart than those in a similar position on the upright plant; which shows that the lower side of the horizontal plant is somehow stimulated to grow a little faster than it would otherwise have done.

This experiment is a very easy one and should be made without fail. You may do the same with the root. The best way is to take a large seed, such as the Broad-bean, and, after it has begun to germinate, and the radicle is about $\frac{3}{4}$ inch long, to mark it in the same way with very thin lines at equal distances of $\frac{1}{16}$ inch and then fix the seed by a strong pin with the root horizontal, on the under side of the cork of a wide-mouthed bottle. Put a little water in the bottle to keep the air moist, and cover all over to keep out the light. In a few hours the tip will have begun to bend downwards and will go on growing downwards. You may turn the bottle round, so that the tip of the root is again horizontal, and it will again bend downwards. No matter how often you repeat the experiment you will find that it is only that part which, as shown by the marks, is growing longer that bends down—the older parts which have ceased to grow are incapable of bending.

These experiments with stem and root show that there is in these organs a power of discerning the direction of the vertical. It is not its weight that makes the root bend downwards, for it will do so even in mercury, on which it would easily float, but there is a sense of direction in these organs akin to that by which we ourselves are able to stand upright even on a steeply-sloping hillside and is not anything of the nature of instinct but is due to the action of gravity on something inside the plant.

In the case of roots, this sense is in the extreme tip only, for if the experiment described above be repeated, but with the last $\frac{1}{16}$ of the root cut off there will be no bending.

The downward tendency of roots is termed **geotropism,** and the upward tendency of stems **apogeotropism.**

These tendencies are usually only noticeable in the main portion of the stem or root, being suppressed and apparently absent in the side branches. The branches from the main root are, in fact, fairly horizontal, as you will see if you grow a Broad-bean with its roots in water (and covered up from the light); and in them the tendency is rather to lie across the vertical. This is called **dia-geotropism.**

In many trees the branches slope upwards, but in some they are almost horizontal, being, like the secondary roots, diageotropic.

2. **Light** has also a great influence on the position of the shoot-axis. Take any small actively growing plant that has a fairly straight vertical stem, and put it in a box open on one side but covered in above, so

that light can get to it only from one direction. In a day or so the shoot will have bent round towards the light, and again as in the experiment with the stem laid horizontally, it is only the young growing part that bends. This curving is called **heliotropism,** and an organ which bends towards the light is said to be **heliotropic.** The stalks of the leaves also bend till the blades face the light, at right angles to its direction, and with the upper side towards it. The blades of leaves may in the same way be said to be **dia-heliotropic.** These two actions take place very commonly in nature. We may see examples of it in any garden, in any clump of trees, wherever in fact a plant is shaded on one side.

Most roots, on the other hand, bend away from the light, as can be seen quite easily by repeating the experiment with the germinated bean fixed to a cork, but with black paper pasted more than half way round the bottle, so that light enters only from one side. Roots are therefore said to be **ap-heliotropic.** This apheliotropism of roots is less commonly seen in nature than the heliotropism or the apogeotropism of stems, because, of course, roots are mostly underground. But it can often be seen in the hanging roots of the Banyan, which curve a little towards a less lighted side, generally that on which is the trunk. But as in the other case, so in this, there are a few exceptions, to which we shall have to refer later on.

3. Roots are affected also by **moisture,** towards which they will always make their way, growing into the dampest places in the soil. So that, if, when a plant is watered, the water is only poured just near

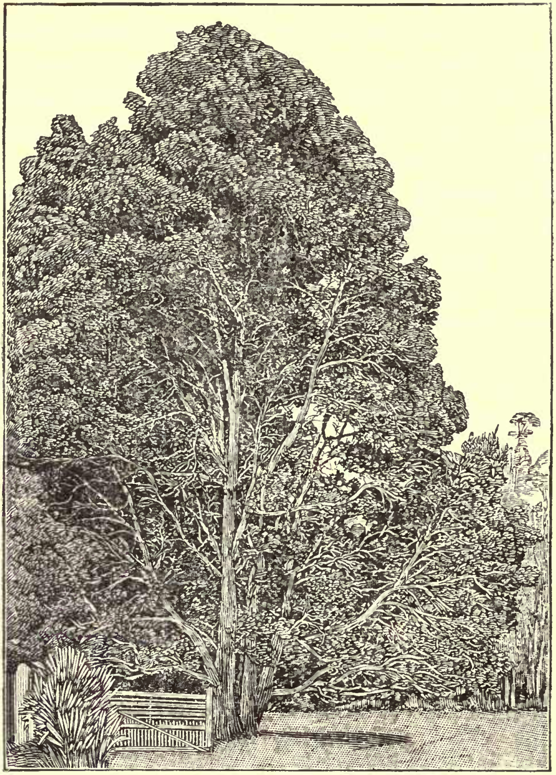

FIG. 20

AN ACACIA MELANOXYLON

Showing how the smaller branches run outwards at right angles to the general surface, i.e. towards the light.

This tree had another one growing in front of it, and too close to allow of branching in this direction, and by its removal the arrangement of the branches has been well exposed.

the stem, as is so often done in gardens, instead of over a wide area, the roots will concentrate themselves there, and in consequence have but a small volume of soil from which to draw both their mineral food-material and water; and if the latter fails, the plant will suffer. Whereas, if the water is poured in a wide circle round the plant, the roots are induced to spread out widely, thus having a much larger volume of soil from which to draw their food and water, and are in consequence less liable to be killed by drought. In nature this is provided for by the outward sloping of most leaves, so that rain drips off them some little distance from the main stem. With a shady tree, whose almost rain-proof crown of foliage is highest in the middle and slopes towards the sides, this is even more the case, for the water drips from leaf to leaf till it drops to the ground in a wide circle. This is why though near the trunk there is shelter, towards the sides the drops are heavier than in the open and the ground underneath wetter. It is here that the youngest roots are in consequence concentrated, and, since they alone possess root-hairs, it is here that the chief absorption takes place. As the branches grow and extend the crown wider, the circle of wetness is widened too, and with it the rootlets invade new ground. Exactly the opposite is however the case with some plants, especially certain monocotyledons, such as ALOCASSIA, CANNA and the Traveller's palm (p. 398), whose leaves slope towards the centre and are channelled so that rain water is directed inwards. This **hydrotropism** of roots is responsible also for the invasion of well watered

pots and beds by the roots of neighbouring trees (see p. 124.)

4. We learnt in chapter iii that, like every other living part, roots respire and give out carbon-dioxide. This gas must be got rid of because too much of it is injurious to living tissues, and it has been proved that a root will grow away from a region rich in carbon-dioxide, and towards one rich in oxygen. This reaction is however much less powerful than the others mentioned.

The necessity of comparatively free interchange of air so as to prevent an injurious accumulation of carbon-dioxide is partly, though not wholly, the reason why plants grow as a rule much better in soil which is kept constantly stirred and loose than in one allowed to get stiff, and why a stiff clay is often sterile. Another reason is the greater quantity of water which, it has been proved by experiment, is lost by evaporation from a hard smooth surface than from loose soil. See p. 345 on the peculiar upright roots of certain mangroves.

CHAPTER X

STEMS

1. In chapter vi we saw that plants could be divided into trees, shrubs, succulents and herbs, by their size and nature—whether woody or not, or succulent; and that they could also be divided into annuals, biennials, multiennials and perennials.

They differ from each other also in habit, i.e. in their mode of life. All trees and most shrubs grow straight upright, but many shrubs and herbs spread flat on the ground (p. 112), or support themselves by **straggling** or **climbing** over other plants, or **twining** round them.

2. TWINERS. Common examples are PHASEOLUS the Bean, IPOMÆA, BONA-NOX the Moon-flower, DÆMIA (fig. 58, p. 257) and CEROPEGIA (fig. 79, p. 352). They are all small plants and found for the most part only on thin-stemmed trees and shrubs.

Some twiners coil in the direction of the hands of a watch, when looked at from above, others in the opposite direction; and various explanations have been propounded to account for this twining. But if we look at a twining plant, such as the common IPOMÆA QUAMOCLIT, L., which has been allowed to coil round

a stick, we shall see that the lower coils slope steeply upwards while the last few are flatter and the tip itself stands almost, if not quite, horizontal. And if we take a plant growing in a small pot and fix it horizontally to a clock-work mechanism so that it may be rotated at a uniform speed, the last few coils will untwist and the growing end become free and no longer twine. And, if a plant is put upside down, the last few coils will again untwist and twine upwards in the same direction, clockwise or anti-clockwise as the case may be.

3. Now all that the rotation on a horizontal axis does is to neutralize the influence of gravity by constantly changing the direction of its action on any part of the plant. No other condition need be altered, for it is the same if the light be from above or from one side. We must conclude, therefore, that the twining is due neither to light, nor to any independent tendency of the plant, nor to a sensitiveness to contact as in the case of tendrils (see p. 111), but to a peculiar reaction to gravity whereby the growing end is kept horizontal like a dia-geotropic organ, and also made to bend sideways, unlike any other part. A little behind the growing point the shoot is weakly apo-geotropic, like an ordinary stem, and under the stimulus of gravity bends upwards so that the coiling is made steeper and at the same time, as may easily be seen by coiling a narrow strip of paper round a pencil and pulling it out, much tighter. When a part of the stem has finished growing in length, it becomes thicker and woody, so that the coils are not easily unwound.

We see, therefore, that the twining of a shoot round its support and its firmness is not such a simple process, as it may at first appear. A peculiarity of the top internodes causes it to bend sideways instead of growing upright; the irregularity of its growth and the influence of gravity cause it to nutate or revolve slowly round; and the upward tendency of all shoots makes the spiral longer and narrower so as to clasp more tightly still; and then with the hardening of its substance, so that the coils do not come loose, the process is complete.

4. CLIMBERS.—Climbers support themselves on trees and rocks in various ways.

In many cases the plant is thorny and its thorns catch on the branches of the larger tree, and prevent it sliding down. This is the means, for instance, whereby the common BOUGAINVILLEA grows up trees or straggles over some support. Some species of *ZIZYPHUS* straggle by the same means over small trees. So to a certain extent does the common LANTANA, and CAPPARIS HORRIDA (fig. 18). In the moist forests (e.g. of the slopes of the ghauts) are many plants of this kind, among these several species of a climbing Palm, CALAMUS (fig. 21),[1] which have very thin stems, in some cases no thicker than an ordinary lead-pencil, profusely supplied with long straight thorns by which they are supported in the thick vegetation, and grow to immense heights, attaining several hundred feet in length.

[1] The stems of these climbing Palms—Rotangs—are commonly known as 'canes', and used for making the ordinary split-cane floor-mat of Indian houses, the seats of chairs, walking sticks (Rattan-cane), etc.

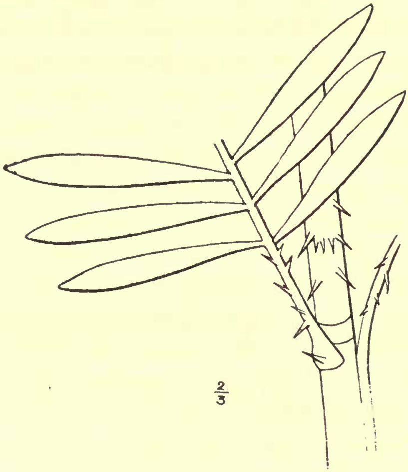

FIG. 21

A CALAMUS

Part of the stem and of a leaf of a climbing palm showing spines.

On the high, more open parts of the hills the wild Rose, and various species of RUBUS (Bramble) straggle by the aid of prickles in a similar way, but with the exception of the climbing Palms, none of these **thorn-stragglers,** as we may call them, grow to any great height.

Turning now to plants which may really be said to climb, and not merely straggle over the others, we find that they attach themselves to their supports by roots, petioles or tendrils.

Examples of **root-climbers** are those thick-stemmed climbers so common on large trees in Indian gardens, PHILODENDRON and POTHOS. These plants develop on the side next to the supporting tree, numerous short roots, which are, of course, adventitious. That they are roots and not a specialized form of some other organ, is shown by the fact that they grow out from inside the stem, breaking through the epidermis, for this we learnt in chapter ii is a characteristic of roots as distinguished from leaves or branches.

The cracks in the outer tissues, by which the roots break through, can be easily seen with the naked eye.

These roots grow as they do, because they are insensitive to gravity, but like normal roots very sensitive to light. This causes them to grow out from the darker side of the stem, that next the tree, and turn into crevices in the bark.

Other common garden plants which climb by roots are FICUS SCANDENS, a small creeper, and HOYA CARNOSA, the wax-flower. The English Ivy is also a root climber. Many orchids and a few ferns, though

FIG. 22

GLORIOSA SUPERBA

they can hardly be said to climb, attach themselves firmly to trees by similar roots. (Epiphytes.)

The common garden Potato-creeper — SOLANUM SEAFORTHIANUM will cling on any thin support, such as a wire, by curving the **petiole** round it. So also does the garden 'Nasturtium' (TROPÆOLUM) and the Pitcher plant (NEPENTHES), a native of America. In GLORIOSA SUPERBA, common enough in hedges all over South India, the leaves have long extensions which coil round any available object (fig. 22).

It has been proved that in such cases the coiling is due to the outer side growing more rapidly than the inner, because stimulated to do so by the friction of the object touched.

In other plants occur special holding organs, called **tendrils,** which, whatever their morphological nature, are merely thin threads very sensitive to contact with any rough surface, and readily twine round any object.

If we examine the tendrils of the Vine, ANTIGONON, PASSIFLORA the Passion-flower, Pea, CLEMATIS or any other tendril-climber, we shall find that in every case the fully-formed mature tendril is coiled up like a spring, acting just as a spring in allowing itself to be stretched and contracting again. The direction of the twist of this spiral, it will be noticed, changes one, three or some odd number of times, which shows that the spiral is made after the end has fastened to the support. We have only to tie a piece of string or tape between two points, and twist it up in the middle to see that the direction of the spiral must be different at either end.

The tendril is carried round by a revolving movement similar to that of a twining stem, and if thus,

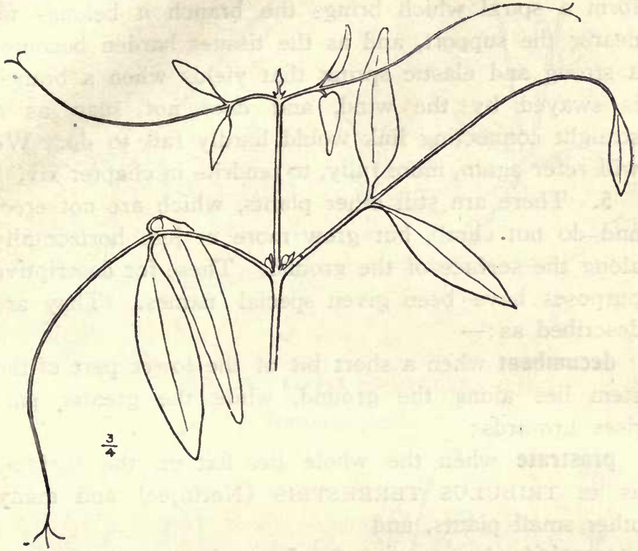

FIG. 23

BIGNONIA GRACILIS

Showing tendrils

or by the wind, it is brought into contact with some thin stem that is not too smooth, coils round it, because the stimulus of contact with a rough surface (it won't round a smooth glass rod) causes the outer side to grow more quickly than the inner. Most tendrils are branched at the top with three curved prongs, which easily catch on any rough objects. When several coils have been formed, the tissues become woody and tough, so that the coils are made fast and

cannot become uncoiled with any ordinary pull. The rest of the tendril then twists round its axis so as to form a spiral which brings the branch it belongs to, nearer the support, and as the tissues harden becomes a strong and elastic spring that yields when a branch is swayed by the wind, and does not snap as a straight connecting link would hardly fail to do. We will refer again, more fully, to tendrils in chapter xiv.

5. There are still other plants, which are not erect and do not climb, but grow more or less horizontally along the surface of the ground. These for descriptive purposes have been given special names. They are described as:—

decumbent when a short bit of the lower part of the stem lies along the ground, while the greater part rises upwards;

prostrate when the whole lies flat on the surface, as in TRIBULUS TERRESTRIS (Nerinjee) and many other small plants, and

creeping when roots arise from the prostrate stems and branches as in LIPPIA NODIFLORA (fig. 24).

In sandy places, especially near the sea, creeping plants are very common, and one of these—IPOMŒA BILOBA is characteristic of tropical seashores. Its leaves are borne on stalks at intervals of six inches or more along thin shoots which grow forward on the surface, but are soon covered by the sand which is driven by the wind along the beach. In this way they become under-ground branches, and if they are all pulled up, roots will be found growing down from the under side of the nodes, and running deeply into the sand, while the leaf-stalks may be short or long, but always

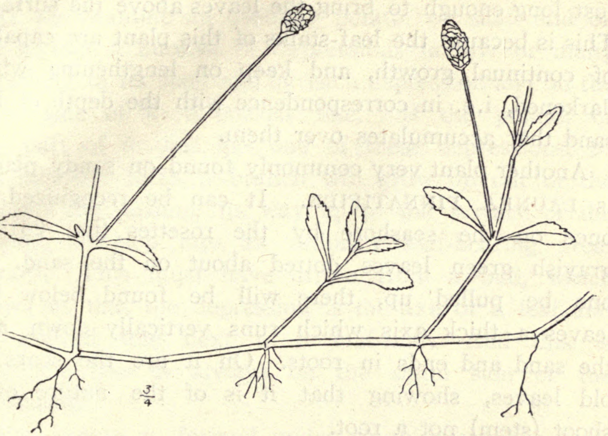

FIG. 24. LIPPIA NODIFLORA

A creeping plant

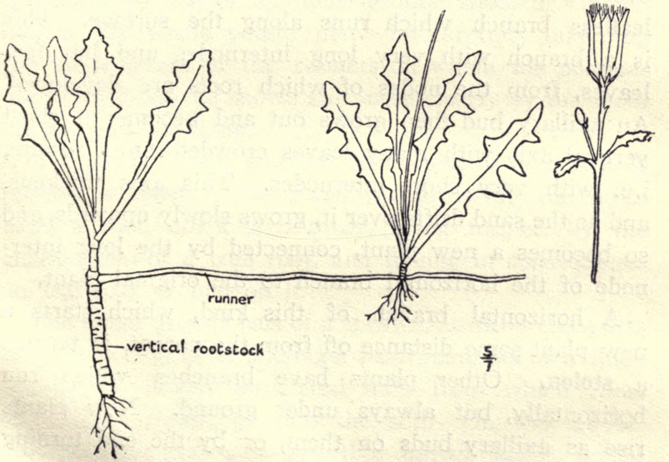

FIG. 25. LAUNEA PINNATIFIDA

just long enough to bring the leaves above the surface. This is because the leaf-stalks of this plant are capable of continual growth, and keep on lengthening when darkened, i.e. in correspondence with the depth of the sand that accumulates over them.

Another plant very commonly found on sandy places is LAUNEA PINNATIFIDA. It can be recognized at once on the seashore by the rosettes (fig. 25) of grayish green leaves dotted about on the sand. If one be pulled up, there will be found below the leaves a thick axis which runs vertically down into the sand and ends in roots. On it are the scars of old leaves, showing that it is of the nature of a shoot (stem) not a root.

6. A shoot axis (stem) which, like this, is under ground, is termed a **root-stock.** In LAUNEA nearly every plant is attached to some other one by a thin leafless branch which runs along the surface. This is a branch with very long internodes and but few leaves, from the nodes of which roots are developed. An axillary bud then grows out and becomes a short vertical axis with many leaves crowded into a rosette, i.e. with very short internodes. This axis thickens, and as the sand drifts over it, grows slowly upwards, and so becomes a new plant, connected by the long internode of the horizontal branch to the original plant.

A horizontal branch of this kind, which starts a new plant some distance off from the parent, is termed a **stolon.** Other plants have branches which run horizontally, but always under ground. New plants rise as axillary buds on them, or by the end turning upwards. Such branches are also termed **runners.**

If we examine an ordinary potato, we shall find on the surface a number of depressions (a few or many according to its size) and by each depression and on the same side of it, a curved line. If the potato, or any part of it that has one of these depressions, be put into the earth, a branch will grow up out of the hollow, and pushing its way up to the surface of the ground, develop into an ordinary leaf-bearing stem (shoot). This must have arisen from a bud, which shows us that the depression is the axil of a leaf and the curved line next it, a leaf-scar. And this is why the line is always on the same side of the depression.

The potato is formed under ground, but the leaf-scars and buds (in the depressions) show that it is of a shoot-nature, not a root. It is in fact a specially thickened portion of an under-ground shoot or runner, and if the whole potato plant be carefully taken up the shoot-nature of the runners on which the potatoes are formed will be shown still more clearly by the small scale-leaves on them.

A thickened part, whether of a shoot or of a root, is termed a **tuber.** The Sweet-potato is on the other hand a root, not a stem-tuber, being formed by the enlargement of a true root, and having in consequence no leaf-scar or bud on it.

The under-ground part of a CANNA, ACORUS CALAMUS the Sweet flag, or of a Ginger-plant, consists of a thick whitish or brown horizontal axis from which roots arise and spread out into the soil. On this under-ground horizontal axis are thin brown scales, which are larger towards the end where the axis turns up

and becomes the leafy stem, and appear to pass gradually into the ordinary leaves. We conclude, therefore, that these scales are leaves reduced to mere scales, because, being underground, they cannot do the ordinary work of leaves, and that therefore the axis is part of the shoot, and not a root—just as is the under-ground branch of the potato plant, only here the axis is much thicker and the internodes very short. An under-ground stem of this kind is termed a **rhizome** (which means root-like), or sometimes **root-stock,** and is of the same nature as the root-stock of LAUNEA, except that it is horizontal instead of vertical.

In a few cases the part which comes up above ground is not the end of the horizontal rhizome itself, but a side branch developed from a bud in the axil of one of the scale-leaves. But in most cases (e. g. in CANNA and ACORUS CALAMUS) the end of the rhizome itself turns up, and becomes the leafy shoot, and its horizontal growth is continued by a lateral branch, so that the whole horizontal under-ground part is a sympodium (chapter viii, section 2).

In some plants again, e.g. CROCUS and COLOCASSIA, there is a very thick and short root stock, of the shape of a ball and covered with thin papery scales, which like those of the Canna rhizome, are reduced leaves. This is termed a **corm**. At the beginning of each growing season, a terminal bud shoots up from the apex of the corm, and becomes a leafy shoot bearing leaves and flowers, and dies down again at the end of the season. New corms are formed at the side of the old by development of the axis of axillary buds.

The **bulb** of which common examples are those of the so-called garden 'Lilies'—EUCHARIS, CRINUM, and PANCRATIUM, is another form of under-ground shoot, but this unlike all the others has a very short axis on which are many thick leaves closely crowded together. It is in fact a bud, the leaves of which are very thick and large. In some bulbs (e.g. the onion), the outer leaves completely overlap and enclose the inner, and the outermost of all are very thin, like paper, and brown. In others (as in LILIUM) all the scales are alike thick, and the outer are shorter so that the surface of the bulb is rough or **scaley,** not **smooth** as in the onion. Some of the scales are not merely reduced leaves, but are the bases of the green leaves which were formed during the proceeding vegetative season, and whose tops have died down and withered away.

7. Now if we ask what are the reasons for all these different kinds of shoots, why some plants climb and others creep, why some have stolons or bulbs or rhizomes, we shall find the answer by keeping in mind the work that a plant has to do, and the kind of soil and situation in which each grows.

8. It is in places where the soil is too thin and shallow to allow trees and shrubs to grow, that we find the annual type at its best. On the slopes of hills and in valleys, where the rainfall is good so that there is plenty of moisture and the soil is rich and deep, grow, unless destroyed by man or other animals, the finest specimens of the opposite type—tall well branched trees under whose shade there is generally a thick undergrowth of such shrubs and perennial herbs,

as can do without much light, and luxuriate in the cool damp air.

It is in such places too that we find most climbing plants; so numerous, indeed, are they in most tropical forests, that one rarely sees a tree without some climbing plant hanging from its branches or twined round its stem. By supporting themselves on the sturdier trees these can, with very little expenditure of constructive material, and therefore also of time, reach to considerable heights, and so obtain the necessary light and air. Their flowers too can be exposed to the sunshine and to the visits of insects (which as we shall see later, is of great advantage to the race), while their seeds can be scattered from the great height more widely, by wind or birds.

But in loose sandy soil, where trees cannot grow so well, and where there is little shade, and too little moisture to support a large number of plants, are found those of exactly the opposite kind—prostrate and creeping plants. These spread their weak branches along the surface of the ground, and thus save in part the material that would be required to make stiff upright stems. Their leaves are developed not all round the axis, but mostly to right and left, in one plane, and so face upward to the light, at the same time shading the soil and keeping it a little cooler and less dry than it would be if fully exposed to the sun, whereby a little more moisture is available for the plant. Creeping plants, whose branches send down roots on their own account, can spread more widely that those which are merely prostrate, for they increase their supply of water by drawing on a larger area.

Again in countries which have two well marked seasons to the year, a warm moist period when plants can grow actively—(as after the rains in India, and during the early summer months in temperate climates), followed by a very hot and dry, or a very cold season, when all tender herbaceous vegetation is killed off, it is of advantage to a plant if it possesses some part that will live on through this latter period, and from which new shoots can spring up as soon as ever the climate allows, thus taking an early advantage of the favourable season.

The need of this perennial part is supplied by the bulb, corm, tuber or root-stock as the case may be. It always contains a large quantity of water to enable it to live on during the season, when the roots cannot supply moisture because of the dryness or the cold, and also a certain amount of carbonaceous food-material, packed away generally in the form of starch as in the potato and other stem- or root-tubers, but sometimes partly as sugar, e.g. in the onion-bulb. These carbohydrates are used up at the beginning of the growing season to make the new shoot, and if a young potato plant be dug up, the tuber from which it grew will be found an empty and shrivelled skin, or a mere slimy mass much less than its original size.

During the vegetative season the first work of the plant, after making its stem and leaves, is to provide for the seeds. In them nitrogenous and carbonaceous food-material is packed away in even more concentrated form and with scarcely any water, and it is only after the year's seeds have been provided

for, that a new bulb or continuation of the root-stock is formed to carry on the plant to the next season, and to provide for its new shoot. We can see from this that, if we wish to move a bulb or root-stock from one place to another, we should do it at the end of the growing season, and after all the leaves have withered and fallen. To move a bulb while it is in flower, as people, who, finding a pretty flower growing wild, and desiring to have it in their garden, so often do, must nearly always prove a failure, because the bulb is then at its weakest, and as the roots are destroyed in the moving, the plant suffers severely.

We can see too, that the larger the bulb or tuber, and the more the water and food material packed in it, the stronger and larger will be the new shoot and leaves that spring from it, and therefore the more food will the new plant be able to make, and the stronger and more numerous the seeds that it can distribute.

A horizontal rhizome has this advantage over a vertical root-stock, a corm or a bulb, that the whole plant moves on just a little each year to a fresh piece of ground.

Runners and stolons are more useful still, for they start new plants growing well away from the parent, providing them with food and water from the mother-plant, till they are sufficiently rooted to take care of themselves, and reproduction thus takes place more quickly and more certainly than by seeds. Gardeners make use of this habit to propagate many useful or ornamental plants, as the Strawberry, Raspberry,

VERBENA and London pride. But runners cannot make their way through very hard earth, and we find them mostly on plants that, like the Potato, naturally grow in loose soil.

CHAPTER XI

ROOTS

1. The first root arises as we saw in our germinated seeds as an extension of the radicle. In nearly all trees and shrubs and in many herbs, this grows on as a strong main root, pushing its way downwards, and giving off branches which at first grow nearly horizontally (showing that they are dia-geo-tropic) and themselves branch again in all directions. These smaller branches grow out in any direction, without reference to gravity, but only towards dampness. The root branches start always from the youngest parts, so that those nearer the ends are younger and shorter than those further back, as may be seen very well on the seedling of a Broad-bean grown in a glass bottle.

When the first root grows on strongly like this, it is often termed a **tap-root.**

But in many plants (for instance with the common Bean) the end of the main root soon dies and its place is taken by a large number of smaller roots which arise at the base of the hypocotyl, and branching out in all directions, are of much the same size and importance. These are termed **fibrous.** Most

MONOCOTYLEDONS and nearly all plants that grow in the mud at the bottom of tanks or in very wet places, have roots of this kind and not tap-roots.

The difference between tap-roots and fibrous roots is not only one of size. A tap-root strikes down deep into the ground, fibrous roots remain nearer the surface, and if we examine plants carefully, we find that the root-system is not a mere chance result depending on the tap-root being injured or not, but that, except when forced by the nature of the ground, some kinds of plants have always deep roots others always shallow, and a knowledge of this is invaluable in agriculture or gardening.

Trees are mostly deep rooted—those whose roots are shallow are much less firmly held on the ground and much more easily upset in a storm of wind. But of shrubs and herbs, many have roots which keep close to the surface of the soil, and are therefore easily injured if the soil is disturbed, soon suffer if it becomes too dry, and as quickly revive after a shower of rain. Fruit-trees are often of this type—the Coffee-bush for instance is a shallow rooting tree, which must have the surface soil kept constantly moist and undisturbed, and readily responds to a surface dressing of manure. A deeply-rooted tree does not impoverish the soil, for it draws its food-materials from deep down in the ground. Rather, it slowly enriches it by the decay of the leaves and branches it sheds. But when a number of shallow-rooted shrubs are growing, the surface soil is soon impoverished and must be constantly manured, and a little consideration will show that if we want our

shrubs and herbs to grow well, we must not put them near shallow-rooted trees. In a garden or coffee estate deeply-rooted trees do no harm, but are rather good as explained above, shallow-rooted trees like species of FICUS, the Banyan, Fig, etc., and PITHECOLOBIUM, the Rain-tree, are fatal. Every gardener knows that pots left under a Banyan tree soon get infested with the Banyan's roots, which are attracted thereto by the water poured into the pots and the rich manure they contain. A Rain-tree has in the same way a depressing effect on any beds of flowering plants, that may be within the range of its roots. So has the ACACIA MELANOXYLON.

2. In Cholam, Wheat, and other cereal plants, the roots are all fibrous, and some come from the stem above the scutellum—that is above the hypocotyl. Of these the lowest are the eldest, the uppermost the youngest, exactly the opposite of what we find in the ordinary branches of a tap-root.

Roots which arise like these, not from another root, but from the stem or branches, are termed **adventitious.**

At the base of nearly every Coco-nut palm (a MONOCOTYLEDON) can be seen a number of these fibrous adventitious roots, radiating out into the ground.

Perhaps, however, the most familiar and most easily recognized of adventitious roots, are those which hang down from the branches of the Banyan tree, and will, if left undisturbed, grow into the ground, becoming after a while, thick stem-like pillars. But that they are roots and not a peculiar kind of branch, is shown by the entire absence of leaves or scales, and by the little brown root-cap which occurs at the end of each.

Moreover, if the tip be eaten by animals or otherwise damaged, branches soon arise and these can be easily seen to come out from the inside by narrow cracks, and not from the surface as, we have learnt, do the branches of the shoot.

That they ultimately come to look so like stems, is due to the fact that though quite different in structure when very young, roots increase in thickness, exactly as do stems, and form cork and bark in the same way. These adventitious roots of the Banyan serve of course to support the branches, and so enable one tree to grow enormously and cover a great space of ground. There is one very famous tree in Calcutta whose stem-like supports number about 500, and bear a crown of branches of over 900 feet in circumference, and other trees famous for their size are found in Madura and other places. The adventitious roots of cereals and palms, also act as extra holdfasts and supports to keep the stem upright. Such supporting roots are better developed in the Screw-pine, PANDANUS, where they are sometimes a couple of inches thick, and have very large scaley root-caps (fig. 2).

Several trees which habitually live in the mud-flats of tropical seashores, also have adventitious supporting roots which, like those of Pandanus, grow down obliquely into the mud and form a much better and firmer support for the plant than a single thick stem, which might be washed away by a strong tide, could do. These trees are called MANGROVES, and they grow very commonly in the tropics by the mouths of rivers and wherever the seashore is soft and muddy.

The roots which arise from the under side of creeping plants like LIPPIA, and those by which, as we have already learnt in chapter x, some climbers as like PHILODENDRON and PIPER, cling to their supports, are also adventitious. In the latter the geotropic tendency is altogether absent while the apheliotropic is very strong, so that they arise only on the darkened side of the climbing stem, and make their way into the cracks of the bark of the supporting tree. The hanging roots of the Banyan, on the other hand, are so much more sensitive to gravity than to light, that they grow straight downwards, and can only very occasionally be seen curving towards the main trunk—i.e. to the shadier side.

Adventitious roots will arise on almost any piece of a shoot axis, that is buried in the ground, or even merely darkened, and on this account many plants can be easily propagated. If pieces of the common Sugar-cane or Prickly-pear, for instance, be stuck into or even laid flat on the ground, roots soon grow out from the nodes (where the spines are) and make their way into the soil. The ordinary way of propagating the common potato, sweet potato, hariyali-grass, and many other plants depends on this property. In the case of the common potato, a tuber (which we have learnt is part of the shoot) or any part of it that contains an 'eye' (or bud), may be used. In the case of the Sweet potato, the tuber is part of the root-system, but from any portion of the stem, as long as it contains a node, roots and buds will grow out.

Gardeners make use of this same habit—of roots growing out of buried or darkened portions of a shoot—

to propagate many of our flowering or ornamental shrubs, which either (like the HIBISCUS) do not produce fertile seeds, or would not come up exactly the same from seed—as in the case of the CROTON and PANAX. In some cases a branch is bent down to the ground, and a part of it kept covered with damp earth till roots have formed. In others, earth is put round the stem or branch, bound on with a piece of cloth and kept moist. When the roots have grown, as they soon do, the branch can be cut off, and planted separately.

Adventitious roots and buds will even arise in some cases from a leaf, e.g. from the notches in the edge of the leaf of BRYOPHYLLUM without being put into the ground, or even darkened, as every one knows who has had one hung up in his house. If a leaf of a BEGONIA is cut off and the base stuck into moist earth or sand, roots will soon grow out, and after them a bud, also adventitiously, and so a new plant be produced. This is a common way of propagating these plants.

There is one family of plants, the GESNERACEÆ, in many of which this happens in the natural state. In DIDYMOCARPUS (one of this family) after the seed has germinated, one of the cotyledons dies, as also do the stem-bud and the radicle. The remaining cotyledon grows till it becomes a very large leaf, lying flat on the ground. At its base adventitious roots strike down into the soil, and an adventitious bud becomes the flowering stem.

3. In chapter iii we learnt that one of the chief functions of roots was to fix the plant firmly in the soil, and that the great combined length of its many

branches, and the combined effect of their countless root hairs made roots stick very tight in the ground. Some roots, however, not only keep the shoot firm, but actually **drag** it deeper into the soil. This is especially the case with some monocots that have horizontal rhizomes, e.g. CANNA. If the soil from above the rhizome be scraped away, so that the latter is not so deeply buried, the roots contract and drag it further downwards.

There are some plants too, whose roots have no root hairs. They are mostly water plants, whose roots being always in water do not require hairs—and many land plants which normally have root hairs, do not if grown in water.

4. SPECIAL FORM OF ROOTS.—We have already referred to the Sweet-potato as being a root-tuber. The garden DAHLIA is another plant whose roots become swollen and tuberous. In the common country Radish, it is the tap-root that becomes swollen, and the branch roots, which arise in two vertical lines, on either side of it, are quite thin and small. (In the English radish the tuber is formed from part of the hypocotyl). These **tuberous** roots, have the same importance as rhizomes, stem-tubers and corms—carbonaceous food-material, mostly in the form of starch, is stored in them for the use of the next year's shoot and its seeds.

Very peculiar roots occur on some plants which grow not in the ground but on trees. These **epiphytes,** as they are called, cling to trees by small roots which like those of root-climbers are strongly aphelio-tropic, and making their way into the crevices of

the bark, absorb some of the water that runs down the branches and trunk of the tree after every shower, and also any mineral matter that may be blown up from the ground as dust, and be dissolved in it. But being entirely unconnected with the ground, this, and the little rain that actually falls on them is all these plants get, and therefore as one might expect, they grow only where the air is moist and rain falls frequently. On the roads of Singapore which has a very damp climate, almost every tree has on it some—often very many—epiphytic ferns. In addition to these clinging roots, some epiphytes (not ferns) have others which are about the thickness of an ordinary lead pencil, and hang down freely, being apparently quite insensitive to light, or if any thing, attracted not repelled by it. The orchid, VANDA ROXBURGHII, is a fairly common Indian epiphyte which has these roots well developed. When dry, the root looks quite white, but if moistened, greenish. Breaking it with the fingers, one can easily separate the soft outer white part from a firmer central part. This soft outer portion, is composed of very loose spongy tissue, with lots of little spaces empty of everything except air, and looks white for the same reason as the foam of the sea, or the froth on fermenting toddy, looks white, that is, because the light is reflected in all directions from numbers of tiny bubbles of air. When this tissue is wetted, the air is replaced by water, and it becomes more or less transparent so that the green colour of the central part shows through.

This **aerial** root then differs from all ordinary roots, in having a green layer overlaid by a spongy one.

This porous spongy layer, readily absorbs any water, that, like rain, may fall on it, and also allows air to reach the green layer underneath, and thus these roots act both as true roots in absorbing moisture, and also like leaves in assimilating carbon from the air. It seems very likely too, that nitrogen in the form of ammonia, produced by the decay of vegetable and animal matter, may be absorbed in the damp spongy tissue and ultimately made use of by the plant.

5. All the types we have been considering have been normal green plants, absorbing their food-materials from soil and air by their own roots and leaves. There are, however, plants which depend wholly or in part on others for their water and food. These are called **parasites** or **semi-parasites,** as the case may be, and the plants they feed on are called their **hosts.**

STRIGA is a very common semi-parasite on the plains, growing on the roots of SORGHUM and other grasses, to which it attaches itself by little round tubercles, called haustoriums. The Sandalwood tree, SANTALUM ALBUM, is another, for it attaches itself to the roots of shrubs, such as LANTANA, by similar haustoriums, and LORANTHUS is a very common semi-parasite on the branches of trees, into which it sends special sucking organs to draw the sap. These semi-parasites have all chlorophyl in their leaves, and are, therefore, able to assimilate carbon and manufacture a certain amount of food-materials for themselves, but they seldom have the full green colour of a normal plant.

The true parasites are quite devoid of chlorophyl and are entirely dependent on their hosts. Some which grow on roots have, like the common CHRISTISONIA of our hills, a short stem and colourless scale-like leaves, or like BALANOPHORA, practically no stem at all, but only a few scales and a mass of flowers forming a large warty lump on the roots of trees. Others like the common CASSYTHA, and CUSCUTA the Dodder, grow on the branches of soft barked shrubs and herbs, looking like strands of yellow string, but attached to the host by numerous haustoriums, and with no leaves. All these parasites and semi-parasites have perfectly normal flowers however much the rest of the shoot may be reduced.

6. In all these types, in the stout trunk of a tree with perhaps its buttressed base, or the thin flexible stem of a twiner, in the weak bifarious branches of a creeping herb, the bulb or tuber of a perennial, and the peculiarities of a parasite or an epiphyte, we see examples of the intimate connexion between form and function which we came across in our study of cotyledons. And this is emphasized by the fact that the flowers whose function of reproduction is, of course, the same whatever be a plant's vegetative habit, are not affected by these differences. A tall tree and a creeping herb, a root-parasite and a shrub, an epiphyte and a climber, may have flowers of the same size and form.

CHAPTER XII

SPECIES AND GENUS

COMMON experience shows us that all the leaves of a plant are very much alike and arranged in the same way on all the branches, though they may differ in size, and though sometimes those which grow on the younger branches are more or are less regular in shape, than those on the older, and in a few plants which grow in water, the submerged leaves are different from those above water. With these exceptions all the leaves of a plant resemble each other in shape, thickness and feel. Every one recognizes too that there are different kinds of plants—just as there are of animals—and that all the members of any one kind however much they may differ from one another in size—that depending so much on external conditions, such as the state of the soil and the amount of water and light available—yet resemble each other very closely in regard to their flowers, general habit and leaves, and differ, especially, in their leaves from those of all other kinds.

We conclude, therefore, that the nature and appearance of its leaves are characteristic not only of the

individual plant, but of the kind, and are thus able to distinguish the different kinds of plants.

Thus we can distinguish easily and at a glance, the Palmyra-palm with its dark-coloured unbranched stem and crown of broad fan-like leaves with ribs and cuts radiating from the base where the stalk is attached, from the Coco-nut whose stem is also unbranched, and marked also with rings across it, but whose leaves are much larger and made up of a number of segments (leaflets) attached to a central stalk, and each folded downwards along its middle. The common Date-palm again, we distinguish easily from the Coco-nut, because of its smaller leaves, and their leaflets, arranged as in the Coco-nut-palm, but folded along their middle line upwards instead of downwards.

The Peepul again, has a much branched stem covered with a fairly smooth grey bark (marked at intervals of a few inches by lines running round the axis) and small undivided leaves which have a long acuminate point, a shiny surface, and long flexible stalks. The Banyan, on the other hand, while resembling the Peepul in being branched, though more widely so, and in its grey-coloured bark, is different in having roots that hang down from the branches and leaves with rather thick stalks, thick blades, blunt ends and a smooth not shiny surface.

Every kind of plant has its own kind of leaf—however much the general shape of the plants may differ.

And if we put a Palmyra fruit in the ground and water it, we know that we may get from it eventually a Palmyra-palm, never anything else. If we sow

seeds of Flax or Wheat or Cotton or Paddy, only Flax, Wheat, Cotton or Paddy, as the case may be, will come up. No one has ever raised Cholam from Paddy seed, nor Barley from Wheat, nor even Jowari cotton plants from Karunganni cotton seed.

Since every plant has sprung (by seed or directly) from another more or less like it, all those of any one kind must be related to each other, and have descended, through perhaps a long past, from one common, or several very similar, ancestors. Such a group (or kind) of plants, all the members of which resemble each other in the more important respects of flowers, general habit and leaves, looking therefore as if all had come from a common ancestor, is termed a **species.**

Coco-nut-palms, for instance, all belong to one species—the Coco-nut species—known botanically as COCOS NUCIFERA. (We shall see shortly why the name is a double one—the second half is the species' own special name). Palmyra-palms belong to another species known as BORASSUS FLABELLIFER. The common Indian Date-palms to another, PHOENIX SYLVESTRIS. All Banyan trees belong to one species called FICUS BENGALENSIS. All Peepul trees to another, FICUS RELIGIOSA.

Now we do not find any species of plant growing wild all over the world. Some grow only in the eastern hemisphere, others only in the western, some are found in the tropics, others only in temperate climates. Coco-nut-palms, for instance, grow quite commonly on the shores of the tropical parts of America, Africa, and Asia, and on all the islands of Malay Archipelago, and the Coral islands of the Pacific,

but even in the tropics not far inland, not, for instance, on the plains of central and northern India, and are quite absent from temperate regions. The common Indian Date-palm, PHOENIX SYLVESTRIS, grows only in India and Burma, being entirely unknown (at least wild) in Europe and America. It differs from the Coco-nut in that it thrives on the plains, far away from the sea.

Paddy again requires a great deal of water and a high temperature and cannot be grown (except perhaps in a small way with artificial heat) in the cooler parts of the world. On the other hand, Wheat (another cereal crop plant) grows splendidly in Europe without being irrigated, and will even live for weeks in ground, the surface of which is frozen hard like ice by the cold.

Thus a species is a group of plants with common wants and common habits, as well as a common appearance; and just as we think of a plant as doing its best to grow strong and reproduce itself, as much as it can, under the conditions in which it finds itself, so must we also think of the whole species, as trying to adapt itself to the districts in which it lives, and to spread as widely as possible over them.

But consider now the three well-known species—the Banyan, the Peepul, and the country Fig. These three species are all trees, they all have alternate leaves, and large cap-like stipules which cover the next leaf (and all above it) in bud, and as the internodes develop, fall off and leave a scar extending like a ring right round the branch. They have this also in common that if a leaf be torn or a branch broken a white sticky juice exudes—

and this does not happen with very many species. Lastly, their flowers are very minute and imperfect, and are massed together inside a hollow structure which eventually becomes a fruit, of a bright red colour and more or less 'fleshy', so as to be edible by animals and men.

Consider again the two common species—the Vayai marum or Neem tree, and the Malaivayai marum. These are both trees, they have alternate compound leaves—in the one case pinnate, in the other bipinnate. The flowers in both cases are not very large and are borne in large branched inflorescences termed panicles, and consist of five sepals, five petals and a staminal tube bearing ten anthers sessile at the top. The fruit in both is a 'drupe' containing one hard stone. It is only in the leaves and perhaps the colour of the flowers that these two species differ. In all other respects they are very much alike.

Take again the three fruiting trees—the Custard-apple (Seetah), the Bullock's heart (Ramseetah), and the Sour-sop (Mooklooseetah). These three species are shrubs or small trees, with alternate rather leathery bifarious leaves and short petioles. Their flowers are borne in much the same way, solitary or in close bunches (fascicles).

In each too, there are three sepals and either three or six petals (three inner and three outer). That is, the sepals and petals are in sets of three, a very unusual number in dicotyledonous plants. They have this too in common that the stamens are very numerous and rather peculiar, having very short filaments and large anthers, each surmounted by a sort of crest—

the continuation of the connective. There are in each of these species also, many carpels which, at first separate, become fused in fruit so as to form one fleshy mass with several black seeds. If one of these be cut open, the endosperm will be seen to be marked by irregular lines running in from the seed coat (technically known as being ruminate).

These three species are thus very much alike in all the important respects of (i) the arrangement of the leaves, (ii) the arrangement of the flowers, (iii) the nature of the flowers themselves even to the minute detail of the stamens, (iv) the fruit, and (v) the seed. Only in the shape of the leaves, and in the appearance and taste of the fruit do they really differ.

In the same way we find in the cooler parts of India (and on the hills of South India and Ceylon) several kinds of ground Orchid which differ in the size of the stem, leaves and flower, in the length of the spur, in the erect or spreading position of the sepals, in their white or purple colour, and in the shape of the lip, but all are very much alike in the arrangement of the flowers on the stem (a spike), in the inferior, twisted ovary, in the large front petal (lip), in the presence of five other smaller petals or sepals, and in the other parts of the flower. All the common Strobilanths of our hills, again have opposite leaves, swollen nodes, and flowers of the same pattern, but differ in habit and in the shape and size of the leaves. The two common garden Cosmeas, COSMOS, the yellow C. KLONDYKE and the pink or white (or purple) C. BIPINNATA, which differ in the much more divided leaves, are in their flowers exactly alike (except in

colour). Many other instances of the same sort of similarity between different species will occur to the reader.

We thus see that just as plants can be grouped into species, species can also be grouped. A group of species possessing in common certain characteristics of flower and fruit, though differing in habit perhaps and in their leaves (characters which we have already learnt are of minor importance) is called **a genus**. Thus the Banyan, the Peepul and the country Fig, belong to a genus known scientifically as FICUS. It is a very large genus, comprising a large number of species, most of them trees, and all with a sticky milk-white juice, large hood-like stipules, and minute imperfect flowers aggregated inside a hollow receptacle, but differing among themselves in their general habit (the Banyan for instance has roots hanging down from the branches, the Peepul and Fig have not), in the appearance of the leaves and fruit and other characters of lesser importance.

In the same way the Bullock's heart, Custard-apple and Sour-sop are three species belonging to another genus named ANONA, because similar to each other in the chief characters of flowers, fruits and seeds, but differing in their leaves, and in the outward appearance of the fruit.

It has been found convenient therefore to give to every species, two names, one of its genus the other its own special name, and it is usually necessary and sufficient in describing a plant to give these two names, the genus always first, the species second. But to add clearness and preciseness to the name, and

to avoid any confusion due to a species being named more than once by different botanists, it is usual to add the name of the man who first gave to the species its name.

Thus the Banyan is called FICUS BENGALENSIS, Linn.: because it was first described and named by Linnaeus, over a hundred years ago. He too, first described the Peepul naming it RELIGIOSA—and it is therefore FICUS RELIGIOSA, Linn. In the same way FICUS GLOMERATA, Roxb. means the species which Roxburgh first described and named glomerata. This is the edible Fig tree of South India.

So too, the Custard-apple is ANONA SQUAMOSA, Linn.: because Linnaeus first named it squamosa on account of its luscious fruit. The Bullock's heart (Ramseetah) is ANONA RETICULATA, Linn.: named such by Linnaeus, because of the net-like markings on the fruit, and the Sour-sop is ANONA MURICATA, Linn. —from the projections on the outside of the fruit.

In a few cases, but only in a few, it is necessary to add another name to describe the peculiar variety of the species meant. This is the case mostly with cultivated plants, which, in process of cultivation have given rise to several varieties like, for instance, the different kinds of plantain fruit. The species is then the wild plant from which these varieties are considered to have been derived, thus the Citron, Sweet-lime and Lemon, are considered to be varieties of one species CITRUS MEDICA, Linn.—the Citron being CITRUS MEDICA, Linn. (proper) the Sweet-lime CITRUS MEDICA, Linn., *var.* LIMETTA and the Lemon CITRUS MEDICA, Linn., *var.* ACIDA. Of most cultivated plants there

are numerous varieties—which are considered to belong to one natural species, because their differences have arisen only in cultivation. All the many kinds of Paddy for instance belong to one species ORYZA SATIVA, Linn., all our garden Crotons to CODIÆUM VARIEGATUM, Blume. Well-defined varieties occur also wild in a few species.

When we have collected and examined a large number of genera, we shall easily see that just as species can be grouped into genera, so genera fall naturally into more or less well-defined **families.** We shall understand the characteristics by which families are distinguished from each other when we have studied more plants in detail, but for the present it may be said that for this purpose we judge by characteristics which are not likely to have been much modified by external conditions, namely, the position of the leaves (whether opposite or alternate), the presence or absence of stipules, and, chiefly, the general nature of the flower.

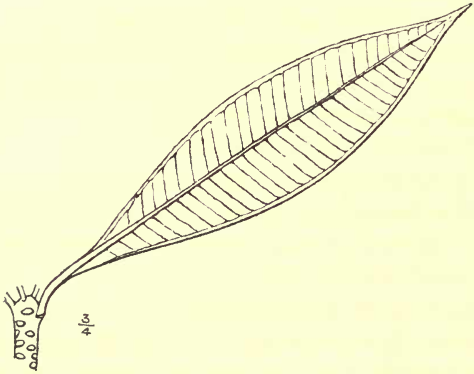

FIG. 26

PLUMERIA ACUTIFOLIA, Poiret

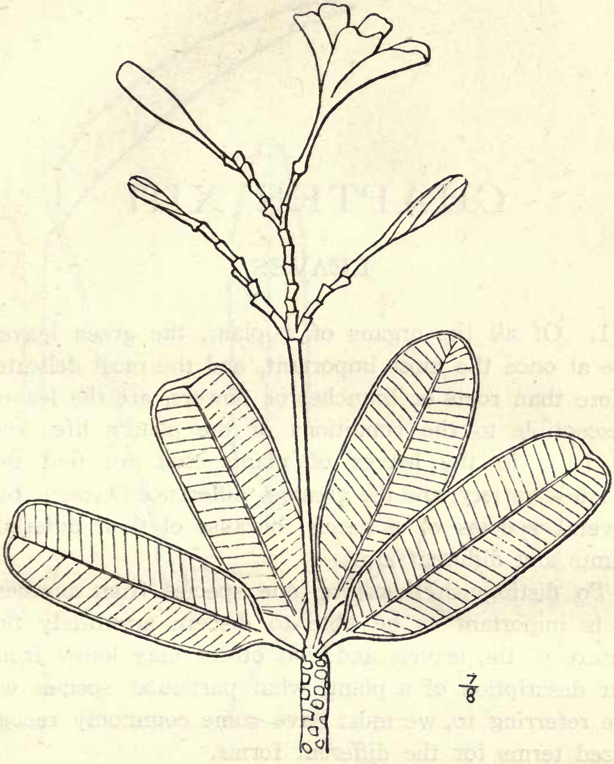

FIG. 27

PLUMERIA ALBA, L.

The Frangipanni

The Pagoda-tree (fig. 26) and the Frangipanni are two species very much alike in almost every respect, except their leaves, and therefore placed in one genus.

CHAPTER XIII

LEAVES

1. Of all the organs of a plant, the green leaves are at once the most important, and the most delicate. More than roots or branches or flowers, are the leaves susceptible to the conditions of the plant's life, and so it is in the leaves of plants that we find the greatest variety, and the greatest difference between the several species of a genus, because of their different wants and different aims.

To distinguish therefore, one species from another, it is important to be able to discern accurately the nature of the leaves, and that others may know from our description of a plant, what particular species we are referring to, we must have some commonly recognized terms for the different forms.

2. A leaf—or any organ if **flat** is described as

linear—if many times as long as broad, like grass, or ZEPHYRANTHES the 'Crocus' of Indian gardens.

oblong—if two or three times only as long as broad and with more or less parallel sides, as in some leaves of IXORA PARVIFLORA and IMPATIENS CHINENSIS (fig. 28), PLUMERIA ALBA (fig. 27).

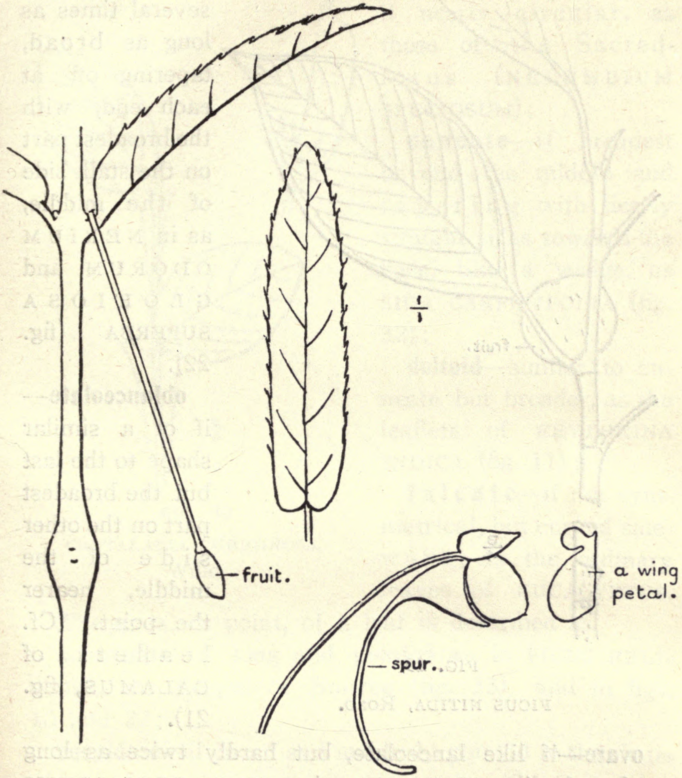

FIG. 28

IMPATIENS CHINENSIS, L.

elliptic—if tapering off at each end and broadest at the middle like an ellipse. As in VINCA ROSEA, and IXORA PARVIFLORA, PLUMERIA ACUTIFOLIA (fig. 26), FICUS NITIDA, Roxb. (fig. 29).

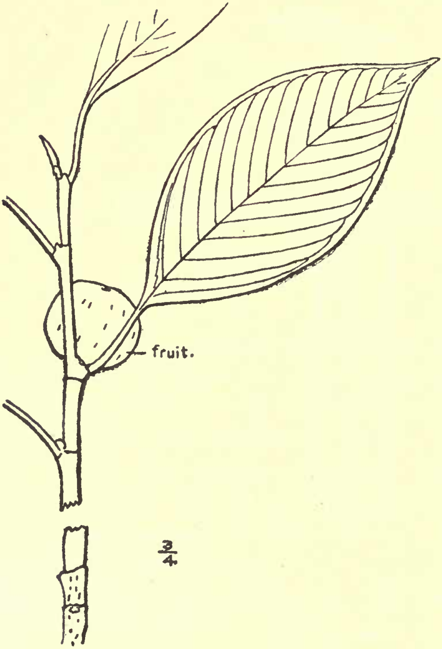

FIG. 29

FICUS NITIDA, Roxb.

lanceolate—if several times as long as broad, tapering off at each end, with the broadest part on the stalk side of the middle, as in NERIUM ODORUM and GLORIOSA SUPERBA (fig. 22).

oblanceolate—if of a similar shape to the last but the broadest part on the other side of the middle, nearer the point. (Cf. leaflets of CALAMUS, fig. 21).

ovate—if like lanceolate, but hardly twice as long as broad, like an egg, as in FICUS BENGALENSIS (the Banyan), CROTALARIA RUBIGINOSA (fig. 30), ABUTILON INDICUM (fig. 31) and figs. 34, 35.

obovate—if of the same shape, but with the broadest part nearer the tip, as in TECTONA GRANDIS (the Teak tree), in CAREYA ARBOREA, LIPPIA (fig. 24) and CAPPARIS (fig. 18).

FIG. 30
CROTALARIA RUBIGINOSA, Willd.

rotund or **orbicular**—if nearly circular, as those of the Sacred-lotus (NELUMBIUM SPECIOSUM);

cuneate—if broadest beyond the middle and tapering with nearly straight sides towards the base, like a wedge, as SIDA CARPINIFOLIA (fig. 32);

deltoid—similar to cuneate but broader, as the leaflets of ERYTHRINA INDICA (fig. 11);

falcate—if not symmetrical, but curved sideways, as the ordinary leaves of EUCALYPTUS.

The apex, or point, of a leaf is described as

acuminate—if long and pointed as in FICUS RELIGIOSA, the Peepul or Bo-tree (fig. 33), and in figs. 10 and 22;

cuspidate—if broad and suddenly pointed in the shape of a cusp, as in HIBISCUS TILIACEUS (fig. 6, p. 41);

acute—if sharp but not prolonged, as in PLUMERIA ACUTIFOLIA (fig. 26);

obtuse—if blunt, as in the Banyan (FICUS BENGALENSIS);

retuse—if obtuse and slightly indented (fig. 34);

emarginate—if with a decided notch at the tip;

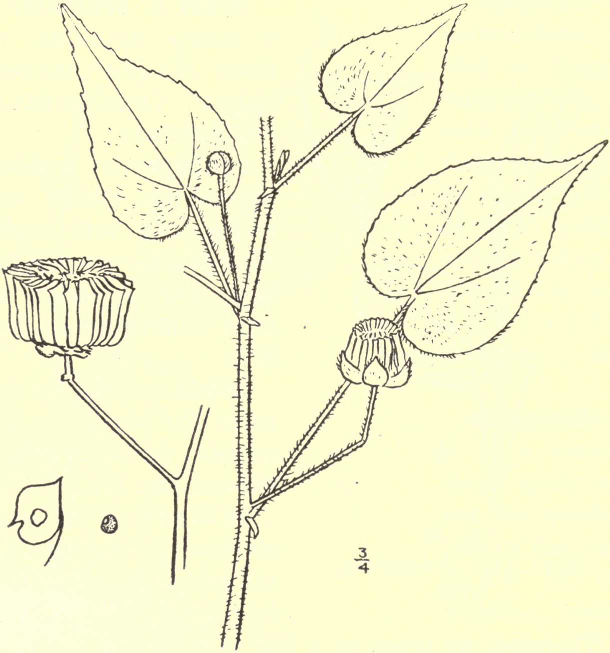

FIG. 31

ABUTILON INDICUM, G. Don.

mucronate—if the mid-rib is prolonged as a short hair beyond the end, as the leaflets of many CASSIAS (fig. 5) and CÆSALPINIAS and CROTALARIA RUBIGINOSA (fig. 30).

The base of the leaf-blade is, when necessary, described as

rounded, acute or **narrowed** as the case may be;

cordate—if indented at the junction of the petiole, in the shape of the conventional heart, as in the

FIG. 32

SIDA CARPINIFOLIA, L.

Peepul (FICUS RELIGIOSA), and most of the CONVOLVULACEÆ and MENISPERMACEÆ, and in ANTIGONON (and figs 31, 35);

reniform—if the blade is broader than long, with a broad shallow indentation in the shape of a kidney, as in HYDROCOTYLE ASIATICA and the common garden plant, PASSIFLORA LUNATA;

auricled or **eared**—if prolonged backwards a little on each side, in two lobes;

sagittate—if these prolongations or lobes are straight and sharp;

hastate—if they diverge sideways as in TYPHONIUM TRILOBATUM.

According to the nature of the edge or margin a leaf is described as

entire—if it is quite even, with no indentations;

dentate—if with triangular indentations or teeth, as in HIBISCUS ROSA-CHINENSIS (the common Shoe-flower);

serrate—if the teeth point forwards as in LIPPIA (fig. 24) and IMPATIENS CHINENSIS, L. (fig. 28);

crenate—if they are rounded, as in HYDROCOTYLE ASIATICA and fig. 35 lowest leaf;

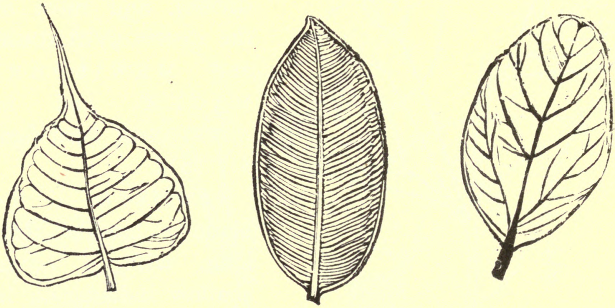

FIG. 33

F. RELIGIOSA, L. The Peepul or Bo-tree F. ELASTICA, Roxb. F. BENGALENSIS, L. The Banyan

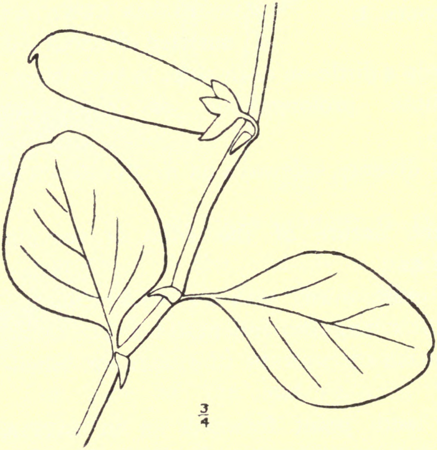

FIG. 34

CROTALARIA VERRUCOSA, L.

undulate or **sinuate** if wavy, as in POLYALTHIA LONGIFOLIA;

lobed—if the undulations extend inwards but not half-way to the centre (fig. 36);

cleft or **fid**—if indented more than half-way as the leaflets of CARDIOSPERMUM (fig. 37);

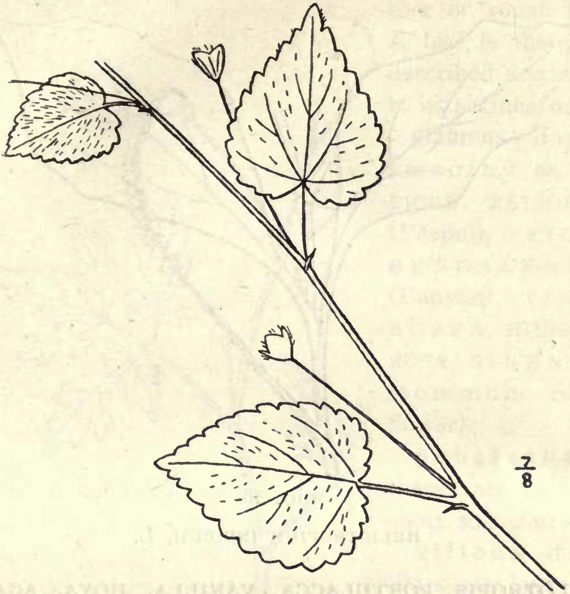

FIG. 35. SIDA HUMILIS, Willd.

partite—if divided almost to the mid-rib.

The last two are used in compound words as **pinnati-fid, palmately-partite.** A leaf divided quite to the mid-rib or petiole would be **pinnately compound** or **palmately compound** as the case might be, or if divided into three sections, **trifoliate** or **ternately compound,** ERYTHRINA INDICA (fig. 11) and CRATÆVA RELIGIOSA (fig. 10, p. 45).

According to the thickness and composition of the blade a leaf is described as,

fleshy or **succulent** if thick and soft on account of the water contained in it, as in BRYOPHYLLUM

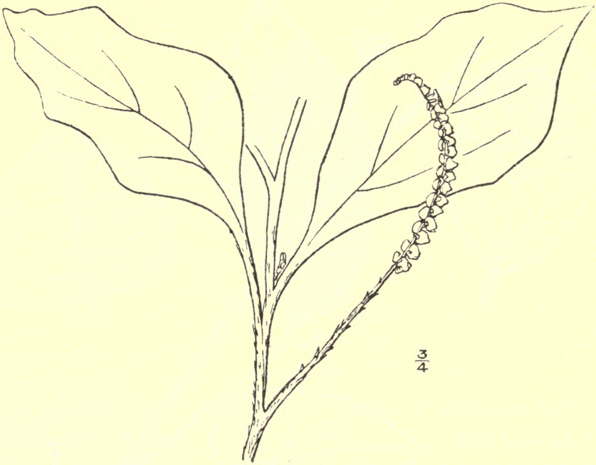

FIG. 36

HELIOTROPIUM INDICUM, L.

CALOTROPIS, PORTULACCA, VANILLA, HOYA, AGAVE, SEDUM the Wall-pepper, etc.

coriaceous—if less thick, but firm and tough like leather, as the Banyan, and many trees and shrubs;

crustaceous—if stiff and brittle as PETRÆA VOLUBILIS, and KIGELIA PINNATA the sausage tree;

membranous or **herbaceous**—if thin and flexible, as in most herbs;

scarious—when very thin and more or less transparent, not green—and applicable rather to scales and stipules, as the scales (glumes and paleæ) which enclose the flower of grasses.

Some leaves are quite smooth, others have hair-like outgrowths, which give the surface a peculiar

FIG. 37

CARDIOSPERMUM HALICACABUM, L.

soft or rough feel. A leaf is therefore described according to its surface as

glabrous—if quite smooth, as in FICUS RELIGIOSA (Peepul), FICUS BENGALENSIS (Banyan), VINCA ROSEA, HIBISCUS ROSA SINENSIS (common Shoe-flower);

pubescent—if there are a few short soft hairs;

villous—if the hairs are long and weak;

hispid—if they are rather stiff;

scabrid—if the hairs are very short and stiff, making the surface feel rough to the touch, as in LANTANA, TRICHODESMA INDICA, CLEOME FELINA (very scabrid like a cat's tongue), LEUCAS ASPERA, NYCTANTHES ARBOR-TRISTIS, POUZOLZIA SCABRA;

tomentose—if the hairs are branched and matted close together, covering the whole surface with a soft, often brown, coating, as in the young parts and buds of many trees STERCULIA, GUAZUMA, ZIZYPHUS (fig. 39) and CAPPARIS HORRIDA;

lanate or **woolly** if they are long and cover the leaf thickly like wool;

silky if long and fine and shining like silk;

glandular if they make the leaf sticky;

ciliate if the edge has fine short hairs like cilia.

Compound words are often used and will be easily understood, as **glandular-pubescent,** meaning that the hairs are glandular and short, **silkily-pubescent,** and so on. Ordinary common words are also used as **velvety** (meaning a soft but shining surface like that of fine velvet).

Some leaves when held up against the light show numerous white dots, due to globules of transparent oil. Such leaves are **gland-dotted.** The oil is nearly always scented, and gives a strong smell to the leaf if it be crushed, as the Orange, Eucalyptus and Myrtle.

The leaf-blade is traversed by veins (vascular bundles) which carry the sap backwards and forwards to every part of the blade, and also serve to stiffen it, for being thin it could not remain flat without this stiffening.

The way in which the veins run is often very characteristic, serving to distinguish plants and even whole families of plants, and is termed the **venation.** There are three main types of venation.

Parallel venation—in the leaves of grasses, Bamboo, Wheat, Paddy and other similar plants, a number of veins enter the blade from the leaf-base, and run more or less parallel to the tip. They are connected by numerous much thinner cross veins which are in comparison quite inconspicuous. This is termed parallel venation.

When the leaves are broader, as in the MELASTOMACEÆ, and ARACEÆ, the veins curve outwards like bows and come together again at the tip. This is really of the same parallel type, adapted to the greater breadth of the leaf, but to distinguish it from the truly parallel type is termed **basal.**

Pinnate venation.—In most leaves there is one central vein termed the **mid-rib** which bears side veins to right and left, these side veins again branching in all directions. This is termed pinnate or feather veining. In some leaves, e.g. in the common Plantain (MUSA), the side veins run straight from the mid-rib to the edge of the leaf, and are connected together by very much smaller cross veins. This is the most typical form of pinnate venation being very like a feather, and is easily torn by a slight wind. In some leaves the side veins are fewer and comparatively strong and run straight to the margin where they end in teeth, but in most cases they curve forwards towards the margin of the leaf and join each other in a more or less regular marginal vein, as in FICUS RELIGIOSA (the Peepul, fig. 33), and PLUMERIA (figs. 26 and 27). The side veins are joined by secondary veins and these branch again, forming a net-work of veins, described often as **reticulate** venation, as distinguished from the parallel cross venation of grasses and the parallel secondary venation of the Plantain leaf.

Palmate venation.—In some leaves, e.g. in Cotton, STERCULIA, *ZIZYPHUS*, three, five or more veins start from the petiole and radiate like the bones in the palm of a hand straight through the blade, ending

generally at the tips of teeth or lobes. This is termed palmate venation. These main veins are generally branched again pinnately, so that the term palmate refers only to the main veins.

In NELUMBIUM (Sacred-lotus) and TROPÆOLUM (Garden-nasturtium) the petiole meets the blade not at the edge but inside it, and the veins radiate out in all directions. This is the most perfect form of palmate venation, and a leaf of this kind (i.e. with the petiole attached inside the margin of the blade) is termed **peltate**. The venation of ZIZYPHUS is very characteristic, veins enter the blade palmately, the two lateral veins branch pinnately, with strong secondary veins towards the outside, much weaker ones on the inside. The middle vein also branches pinnately, but the side veins are here rather weak.

Leaves with parallel venation are always entire, those with palmate venation are either roundish—as in NELUMBIUM and TROPÆOLUM or lobed, the side veins ending in the lobes, as in ordinary Cotton plant, STERCULIA, and many others.

3. In describing leaves, it is usual to begin with its position and nature (simple or compound) and the presence or absence of a stalk; then to give the general shape of the blade (or perhaps of the whole leaf if it is compound) using the terms given in section 2 simply or in combination as may be required; the shape of the base or apex, if it is distinctive enough, follows; then the nature of the edge; of the surface and of the texture; and finally the venation, if characteristic. Thus the leaves of PLUMERIA ALBA (fig. 27) 'are alternate, simple, shortly petioled, oblong,

obtuse or retuse, base acute, entire, glabrous, coriaceous, with prominent pinnate venation.' That of PLUMERIA ACUTIFOLIA (fig. 26) is the same except that it is 'elliptic acute at both ends' instead of 'oblong', etc. The leaves of ERYTHRINA INDICA (fig. 11) are 'alternate, pinnately trifoliate; leaflets with pulvinus and two large glands at the base, broadly ovate-deltoid entire, glabrous'.

FIG. 38

CROTALARIA JUNCEA, L.

Combinations are used to describe intermediate types, thus a broad lanceolate leaf would be called 'ovate-lanceolate', and a narrow lanceolate might be 'linear-lanceolate' (fig. 38).

It is not usual to mention any character which is not prominent. Thus if the point is not specially acute or obtuse it might not be mentioned at all. But it is always necessary to name the position, nature,

shape and margin. In Part II will be found descriptions of common plants, and these should be carefully gone through, with the specimens themselves. It must always be remembered that variations occur in all leaves. We must, therefore, try always to get hold of the most usual or distinctive type and describe that, and avoid abnormal cases.

CHAPTER XIV

BUDS

1. We have already learnt that water is a very important constituent of a plant, and especially so of the young tender growing parts, and that to prevent loss of water the leaves and smaller branches are provided with a thin but waterproof skin, through which are holes (stomas) that can be opened or shut as required, while older parts of the shoot and the roots have a corky covering.

These protective skins do not allow of much expansion and are not therefore suitable for the youngest actively growing ends of the branches, which are, therefore, protected in various other ways.

In some the delicate growing parts are covered by a coat of thickly matted branched hairs (tomentum generally of a brown colour.

This we find in *ZIZYPHUS* (fig. 39), DESMODIUM RUFESCENS, STERCULIA and many tropical trees. But in most herbs and shrubs and in most trees of colder climates the end of the branch is covered with young leaves or with specially formed scales, constituting a bud.

In some the leaves of the bud are not at all different from ordinary leaves, and the younger and smaller are protected by the bases of the older and larger. This we may see in nearly all annual plants and grasses, and in some tropical shrubs and trees as in BARINGTONIA, where the young leaves stand out red and straight at the end of the branch. The outer and first leaves are smaller and obviously scales. In others the outer scales of the bud are brown or whitish, and as the bud opens are thrown off, never becoming ordinary leaves. But if we take a bud of this kind, e.g. of GORDONIA, or the Tea plant, we shall find that inside the thin brown outer scales are others thicker and whiter, while the innermost of all are evidently immature leaves. We can find indeed every gradation between bud-scales and leaves, so that the former must be a special form of leaf. Taking the scales and young leaves off one by one, we find them getting smaller and smaller, the smallest nearest the tip of the branch. In the centre of the bud is the conical tip which with a magnifying

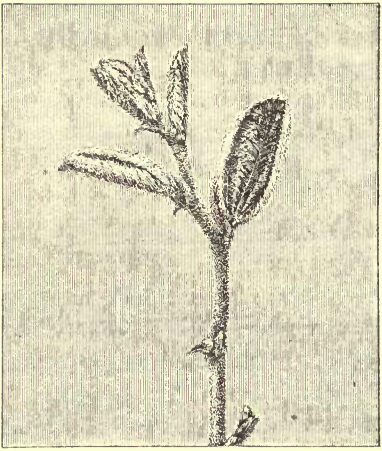

FIG. 39

Young leaves of ZIZYPHUS JUJUBA, Lam.

glass we can see is studded by little humps arranged spirally round. The extreme tip is naked, lower down the humps begin and becoming bigger merge with the young leaves.

Leaves, therefore, arise as humps on the ends of the branches, and the younger are always nearer the tip.

Just above each of the lower larger humps, we may see another smaller one the beginning of the axillary bud.

Examine an opening leaf-bud of BROWNEA COCCINEA. There are a few scales, the outer are small and tough, and hardly grow at all, but the inner grow slightly and eventually protrude beyond them. Inside these are a number of pinnate leaves, the normal leaves of the plant, mixed up with long hair-like things, which spring from near the bases of the leaves and must therefore be modified stipules. The leaves when they emerge hang down for several days colourless and limp, and these leaflets are at first inrolled from either edge to the centre. It is only after some days that the leaflets having opened out turn green and strong, and then the leaves rise up and stand horizontal.

The outer scales soon drop off, their purpose being only to cover the young leaves, and being over with the opening of the bud. In some plants especially those that grow in colder climates, the outer scales are not only tough but sticky with resin or some other secretion, which makes them more impervious to water-vapour.

Now examine a bud of the Banyan. The end of the branch is encased on a thin yellowish organ

which is split and thrown off as the bud expands. It rises on the branch just at the level of each leaf, and is formed of the stipules. The same thing occurs in ARTOCARPUS (the Jak fruit tree) and in other kinds of Figs. Also in SARACA INDICA and a number of other plants. Here, therefore, the bud is protected by the stipule of the previously opened leaf, and is of the same kind throughout the year.

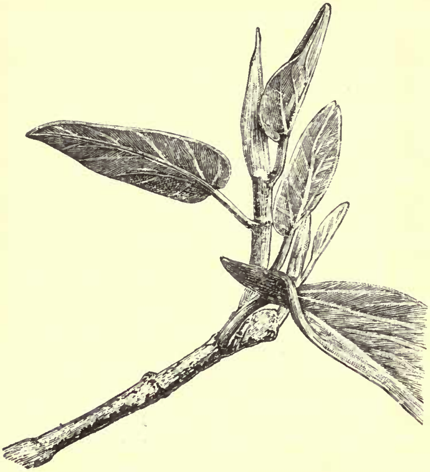

FIG. 40
FICUS BENGALENSIS, L.

But besides the terminal bud of a branch there are buds in the axils of the leaves, though the rule that every leaf has in its axil a bud is not universally followed. Among monocotyledons there are many species which seldom or never branch and though this might be on account of the buds not developing, in many cases it is because there are no buds at all. There are, for instance, none in the axils of most of the leaves of the common Dracaenas of our gardens, nor again in there of most Palms.

Extra buds occur in the ordinary cultivated Coffee tree, where when the terminal bud has been destroyed

to prevent the tree growing too high, a new branch, from just below an ordinary branch, grows up to take its place. The axillary buds are generally small editions of the main and terminal bud of the branch, but are often also protected by the stipules or by the leaf itself, being sunk in a small pit in the base of the leaf stalk, and so quite invisible from outside. This is the case, for instance, with SCHOTIA LATIFOLIA a tree belonging to the family LEGUMINOSEÆ, ADANSONIA DIGITATA, and BIGNONIA MEGAPOTAMICA. In BRASSAIA ACTINOPHYLLA there are stipule-like upward extensions of the leaf base which completely cover the axillary bud.

In IXORA, Coffee and other plants belonging to the family RUBIACEÆ, the axillary buds are covered by the large stipules, which are jointed together and form a tube round the axis. The same in the case in RUMEX the Dock, and POLYGONUM and others of that family, where there is also a tube surrounding the axis just above each leaf.

We see, therefore, that there is considerable variation in buds. There are what we may call **naked** buds—where the end of the branch is without leaves, these only developing later, and is covered only by hairs; secondly **open** buds—where the end is protected by ordinary foliage leaves; and thirdly specialized or **closed** buds—in which some or all the scales are of a special nature, and must be considered as modified leaves or stipules.

There are no hard and fast lines of distinction between these three classes, they merge one into another. Naked buds are found generally in dry

countries, open buds where the air is generally damp and shrubs can be leafy and grow all the year round, and the closed buds in colder climates where they need special protection against the cold of winter, and also in hot countries where vegetation is checked by a hot dry season.

2. Buds also differ in the way the leaves are packed inside them.

In MUSA (the Plantain) and CANNA, the whole leaf is rolled up from one edge to the other. In MARANTA one-half of the blade is smaller than the other, and wraps round it.

In QUISQUALIS (the Rangoon-creeper), ARTOCARPUS (the Jak), FICUS (Banyan, Fig, Bo, etc.), and NELUMBIUM (Sacred-lotus), the leaf is rolled inwards from both edges towards the mid-rib, the under surface of the leaf being outside (see also fig. 39 ZIZYPHUS). In NERIUM, POLYGONUM, and some palms the leaf is also rolled inward from each edge, but the upper side is outermost.

One of the commonest arrangements is for the two halves of the leaf, or leaflet, to be folded together along the mid-rib, e.g. HIBISCUS TILIACEUS (fig. 6, p. 41).

In the grass family the leaves are arranged in two ranks, one on either side of the axis (not spirally) and fit closely over each other.

The fronds of ferns and the leaflets of CYCAS (fig. 41) are peculiar in that they are coiled up along their length, with the tip inside and gradually unroll.

In some plants the leaf (or leaflet) is folded along the main veins, and when just emerging from the bud, shows only these veins towards the outside,

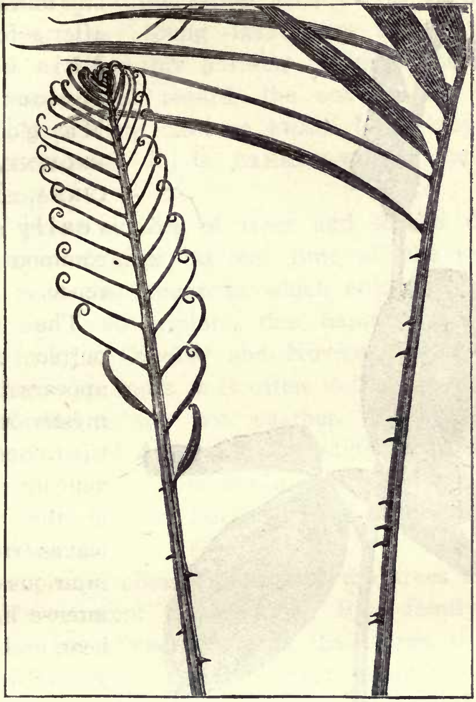

FIG. 41

YOUNG LEAF OF CYCAS CIRCINALIS, L.

the delicate green parts being tucked away inside. This can be well seen in FLEMINGIA (fig. 42).

There is an interesting feature in connexion with the opening of buds of tropical plants, which every one must have noticed. It is that the young leaves are very often of a red or purple colour, and that they generally hang down quite limp, and become

FIG. 42

FLEMINGIA GRAHAMIANA, W. & A.

stiff and flat only after a few days. This is very obvious in the Mango, and in BROWNEA COCCINEA, and is really a very common occurrence.

The red or purple colour appears in some mysterious way to protect the delicate tissues of the young leaves from the injurious effect of intense light and heat, probably by absorbing the rays which compose the yellow-green part of the spectrum, and we do not find this colouring nearly so common, in plants of the temperate climates where the sun is less powerful.

The vertical position of the hanging blade (figs. 6, 11 and 42) also protects the leaf from the rays of the sun, for during the middle part of the day where the sun is vertically over head and his rays are most

powerful, they hardly strike such leaves at all. In some cases the young leaves are stiff and stand vertically upright, this position having of course the same advantage as regards the sun as the hanging one. This is very clear in FICUS (the Banyan and other species, fig. 40) in BARRINGTONIA, and many other plants.

3. A great number of trees and shrubs drop all their leaves together, at one time of the year. In Europe and other countries which enjoy a temperate climate and cold winters, this happens during the autumn months, October and November, just before the winter. In India it is often in February, March or April before the hot weather. Such trees and shrubs are called **deciduous,** to distinguish them from **evergreens,** which are green all the year round, because some leaves fall and new ones are formed continuously.

In temperate climates most of the trees are deciduous, few except those of the Pine family, Gymnosperms, being evergreen, so that there is a very great difference between the appearance of the countryside in summer when all the trees are in leaf, and in winter when they show only the bare leafless branches. On the other hand, in those tropical districts where there is always plenty of rain, most of the trees are evergreen, and vegetation has much the same appearance all the year round. But where there is a season of dry hot weather every year, some at least of the trees are usually deciduous, and bare of leaves during these months, or at least for a few weeks. Common examples of such deciduous trees are ERIODENDRON

ANFRACTUOSUM, whose bare branches sticking out at right angles to the trunk are so familiar a sight in South India. Other common deciduous trees are:—

BOMBAX MALABARICUM (the Silk-cotton tree), POINCIANA REGIA (the Gold-mohur), ALBIZZIA LEBBEK, SLEICHERIA TRIJUGA, PLUMERIA (the Pagoda-tree), ODINA WODIER and Teak. In some of these the young leaves are formed within a few days of the fall of the old ones, and in some POINCIANA, PLUMERIA and BOMBAX, the flowers appear before the young leaves; this indeed is very commonly the case.

The fall of a leaf does not mean a mere tearing away from the branch. In many palms, indeed, the leaf-stalk breaks, and leaves for a while a ragged untidy part on the stem, but with ordinary trees and shrubs, the leaf and stalk fall cleanly away from the branch, and there remains only a perfectly clean scar, the leaf-scar. If one be examined directly after the leaf has fallen, it will be seen to have its own perfect skin, a thin layer of bark. This layer is formed across the petiole before the leaf falls, and gradually cuts the leaf blade off from the sap in the axis. The vessels which conduct the sap are the last to be cut by this layer, and when they are the leaf withers and falls off. So that when the leaf has fallen all the sap which would have gone to the blade, and have evaporated from it into the air, is saved for the plant, while the protective covering of cork which is formed over the scar prevents any further loss.

It seems indeed as if this were partly at least, the purpose of the annual shedding of the leaves—

to cut off all sources of loss of water, during the months when on account of the extreme coldness of the soil, or the great heat and dryness of the air, the roots would be unable to obtain from the ground sufficient water for the leaves.

4. If one goes out on any moonlit night, one cannot fail to be struck with the different appearance of a great many of our common plants—whether herbs, shrubs or trees—owing to a change in the position of the leaves or leaflets.

The Tamarind and the Rain-tree (PITHECOLOBIUM SAMAN) so commonly planted along roads, are good instances of this. Though by day their shade is dense, at night the moon shines easily through. In the Tamarind this is due to the leaflets closing up along the rachides of the pinnæ, and turning so that each faces sideways, and the edge, not the flat side, turns upwards. In the Rain-tree, the leaflets fall downwards, so that they also face sideways, not up and down. The rachis of each pinna falls a little also.

In ARACHIS HYPOGÆA (the Ground-nut) the leaflets turn up a little so as to face sideways rather than upwards.

A very large number of plants with compound leaves behave in a similar manner, the leaflets moving so as to assume a position in which they are vertical instead of being horizontal.

If we examine the leaves of these plants we shall nearly always find that the short stalk of each leaflet and of each pinna or leaf, is swollen at the base, and that this swollen **pulvinus** is the motile

organ. By a contraction of the lower, and expansion of the upper side of the pulvinus, the blade is made to turn down, and by the reverse action, the blade would be brought up.

Many plants with simple leaves, and with leaves or leaflets that have no pulvinus, act in much the same way. Thus, the leaves of SIDA CARPINIFOLIA (fig. 32) rise at sunset, to an angle of about 50^0 to the horizontal, i.e. more than half way to the vertical position. Those of PHYLLANTHUS NIRURI, which is very common among grass (fig. 7), fold along the axis and face sideways. Those of EUPHORBIA ROSEA, another common little herb, move towards the stem and the edges roll back a little. In INDIGOFERA ENNEAPHYLLA (fig. 9), another very common herb which has pinnate leaves, the leaflets rise slightly and each folds up along its midrib. In OXALIS, each leaflet folds up along its midrib, and these fall down so as to face sideways.

A large number of similar cases can be seen without difficulty on any night after sunset, among trees, shrubs, our garden flowering herbs, and the smaller herbs that make up the ordinary Indian 'grass'. The movements are very regular, the sleep position being taken up each evening, and the day position on each morning at definite hours.

These curious movements must be of some use to the plant, and that they are of a protective nature is known, because it has been found that leaves or leaflets which are artificially prevented from assuming their natural 'sleep position', suffer. It is certain that a horizontal blade loses far more heat by radiation

to the sky than a vertical one, and that the latter is therefore less likely to be unduly chilled on a clear night, and less likely, too, to be wetted with cold dew.

To avoid the leaves being chilled, appears therefore to be the purpose of these movements.

CHAPTER XV

EXAMPLES OF HOMOLOGY

In chapter ii we learnt that the three principal vegetative organs of a plant are its stem, its roots and its leaves, and while studying the germination of seeds, we saw that leaves are capable of considerable modification, and may indeed be so altered in general appearance, that their leaf nature is at first quite unrecognizable. The modification in the form of the embryo's leaf is connected, we saw, with the particular work it had to perform, and the particular circumstances in which it was placed. The cotyledons for instance, even when as with RICINUS, the Castor plant, they come out of the seed and turning green behave thereafter like true leaves, are simple leaves with entire margin, however lobed or toothed the normal leaves may be, and this, we saw, is because they thus fit best into the seed, with least waste of room. We learnt too, that some cotyledons are still more unlike leaves, because they are used as stores of food for the seedling plant, the culmination of such modification being reached in the scutellum of the Maize, which is utterly different in every way from the ordinary

leaf, and performs utterly different functions, for which indeed it is admirably adapted, but yet from analogy must be considered as homologous with a leaf.

Then in chapters x and xi we learnt that stems and roots are also capable of modification, so that different forms of these organs occur, and that their different forms depend on the particular work each has to perform. All this shows that we may, and indeed to understand plants properly must, study their organs from at least two different points of view. We must try to find out first what any organ really is, that is to say what it corresponds to in the normal plant, whether to root, or shoot-portion (axis, stipule, leaf, or leaflet), and secondly, why it has that particular form, and what end the modification serves.

The first of these studies is comprised in a special branch of Botany termed **morphology** (the science of form), the second is another branch termed **physiology** (the science of nature and vital processes).

Though distinct branches of study, these must be taken to a certain extent together, for they mutually assist each other, and any inquiry into the modification in shape of an organ would be barren without a knowledge of the physiological conditions.

In the following pages of this chapter, a few common plants that can be found almost everywhere in south India, are described with special reference to some organ that is modified in some respect, and the student is advised to examine actual living specimens of as many as he can procure, and to follow carefully the description given in each case. It cannot be too consistently borne in mind that mere reading

of these (or any) descriptions is almost useless. Each point mentioned must be made out in the actual specimen, and since those described here are all common plants, there should be no difficulty in this.

Homology of thorns

ZIZYPHUS JUJUBA, Lamk, the Jujube

Or on the hills any other species of ZIZYPHUS.

This very common and cultivated tree, grows chiefly in dry places. The young branches and flowers are covered with a thick reddish brown tomentum or layer of short branched hairs set closely together, which protects them from drying in a hot day. It is thickest on the youngest parts and buds, where the protection is most needed (fig. 37).

At the base of each leaf are sometimes one, sometimes two thorns. Their position—for they occur nowhere else—points to their being modified stipules, and towards the end of the youngest branches, they may be found still quite soft like ordinary stipules.

These thorns prevent animals grazing on the branches, and so afford the plant the same sort of protection. We must not, however, from this, jump to the conclusion that the stipules have developed as thorns in order to keep animals off. The change has probably been due to the dryness of the air of the places where ZIZYPHUS usually grows, the keeping off of grazing animals being probably only an accidental result.

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CAPPARIS HORRIDA, Linn.

A small tree which also grows in dry places. It is protected from hot winds and from grazing

animals in very much the same way as is ZIZYPHUS. But the curved thorns also assist in climbing, for by them, the branches catch in the back of other trees and are prevented from slipping back.

We should notice too that in this plant, there are three or four flower buds in the axils of some of the leaves, and that these buds are one above the other, in a vertical line, the oldest (the first flower to open) being at the top (fig. 18, p. 95).

BERBERIS ARISTATA, D.C.

The common Barberry of the hills.

This is a very common plant growing wild on the hills. The branches are armed with sharp slender spines, which are generally three-pronged. Just above each three-pronged spine is a very short branch covered with small scales, and ending in a tuft of leaves, or perhaps a bunch of flowers.

The three-pronged spine may represent one of two things—it may be a branch or a leaf. If it is a branch there must be below it a subtending leaf (or the scar of one), and the total absence of any sign of one shows that the spine is homologous with a leaf. The short branch above it is its axillary branch, the first few leaves of this are modified as small scales, and are followed by the normal leaves. Even if it bears flowers, this axillary branch is a short one of limited growth for the flowers terminate it.

One effect of the spines is clearly to prevent animals eating the plant and the three-prongs are, for this of course, better than one. The leaves are all

the better protected for being on very short shoots, just above and very close to each spine.

PITHECOLOBIUM DULCE, Benth.

The Korukapuli.

This is a very well-known shrub, being frequently grown in hedges. It is rather thorny, and the thorns are in pairs, with a slight round swelling between them. On the younger branches there is between the two thorns of a pair, one (or sometimes more than one), stalk which ends in a small point, and has two branches, each of which again ends in a small point, and bears two blades (leaflets). That these last are leaflets and not leaves is shown by the fact that there are no buds in their axils. There are, we should notice, small glands (not buds) on the main stalk just where it has the two branches, and also at the base of each leaflet.

Now, if there are leaflets the whole must be a leaf, and there being no buds where the main stalk bears the two branches, these latter, with each their pair of leaflets, are two pinnæ (not leaves), and the main stalk is the rachis of a pinnately bicompound leaf, which has only two pinnæ, each with only two leaflets.

The thorns at the base of this leaf must then be modified stipules.

When there is more than one of these reduced compound leaves, between and behind the thorns, the others are the leaves of the shoot which is axillary to the main leaf, and which sometimes does not in

itself develop further. This axillary branch can then be just seen, as a small point, but in other cases it grows out and becomes an ordinary branch. Here again, as in BERBERIS and ZIZYPHUS, protection from grazing animals is afforded to the leaves, by the conversion (or modification) of what are usually soft organs (the stipules and sometimes also the end of the rachis) into hard sharp thorns. And the value of this protection is increased as in BERBERIS by the shortness of some of the axillary shoots, so that the leaves they bear are quite close down among the thorns. At the same time the direct cause of this and other spinous modifications of stipules, leaves or branches is probably the dryness of the air or soil, for when cultivated under very damp conditions these spines often become ordinary soft leaves, etc.

There are other species of the genus PITHECOLOBIUM, some have spines, some have not. One species PITHECOLOBIUM SAMAN, though also not a native of India is very common, being often planted along roads as a shade tree. Among Europeans it is known as the 'Rain-tree'.

There are no thorns on this tree, and each leaf has several pairs of pinnæ, and each pinna several pairs of leaflets. Being a tree, it carries its leaves high up, and well out of the way of grazing animals, so that thorns are not necessary. You should notice that at the base of each leaflet and each pinna, is a pulvinus, and that at about five o'clock every evening the leaflets move downwards, and the pinnæ also. The blades of the leaflets, instead of being more or less horizontal, thus come to be nearly vertical, so that while during

the day, they catch the sun's rays and let very little of the light and heat pass between to the ground below, at night the heat from the earth and the hot air can easily rise up and pass away. It is for this reason that the plant makes such an excellent roadside tree.

Reduction in leaves and leaflets

CASUARINA EQUISETIFOLIA, Forst.

Examine the smaller branches of CASUARINA, a tree, which, though not a native of India, grows very well here, and is planted very commonly in waste sandy places near the sea, for the sake of fire-wood, and also in peoples' gardens in the plains or the hills.

The branches are brown and rough with sharp scales which occur in whorls or circles. On these branches arise slender cylindrical green organs, which, being green, do the work of leaves. But these green organs are not leaves. If you examine one, you will see that it is marked at intervals of about one-sixth inch with a whorl of very small triangular scales. There are shallow grooves too running longitudinally down from one whorl of scales to the next, and alternating with the next set of grooves.

Now, no leaf structure bears whorls of scales, or anything else but hairs or glands.

These green organs are in fact branches, and the small triangular scales which they bear represent leaves, though very much reduced and as leaves quite useless. As we find in nearly all cases of opposite or whorled leaves, those of one node stand not just above, but in lines between those of the next, so here,

the teeth of one whorl alternate with those of the next, and the grooves which run down from between each pair of teeth, alternate therefore with those from the next node (above or below).

There is a small herbaceous plant,

RUSSELA JUNCEA, Zucc. the Coral plant,

very often grown in gardens in India, which shows something of the same habit. The stem and its branches are green and bear whorls of leaves, which sometimes are reduced to mere scales, at others are green and, though small, undoubtedly leaves, while quite large leaves often occur at the nodes. In this plant the change from the ordinary form of leaves to scales is not complete; in CASUARINA it is.

FERONIA ELEPHANTUM, Correa.

The Wood-apple tree.

This tree has a rough bark and many spines on the branches. These spines occur with the leaves, either in the axil of a leaf, or often below a bunch of leaves. But on looking carefully we find that in the latter case there is always the scar of a leaf below the spine, and that the spine is on one side of a bud of which it is really the modified first leaf (see p. 178). When leaves occur above a spine, they arise on an irregular lump, formed of abortive branches which do not develop further, but remain quite short and have only two or three leaves.

The leaves are pinnate and often the rachis is broadened or winged. The leaflets are tough, very smooth, and if crushed smell strongly of aniseed. The

broadening of the rachis increases the area of green tissue which can do the work of assimilation, and being thick and tough this part would not suffer so much in a drought as would thin leaflets. The spines of course prevent animals eating the leaves and small branches, for some animals are very fond of aniseed oil, and here again as before the protection is all the better because of the shortness—amounting almost to total absence—of the axillary branch, so that the leaves are massed together close to the spines.

CITRUS MEDICA, L.

The Orange tree.

The branches are green and angular, the leaves are spirally placed, i.e. are alternate, and at the base of each is a thorn, placed somewhat to one side of the minute axillary bud. On the upper branches of older trees these thorns are sometimes replaced by leaves, from which we must conclude that the thorn is not a modified branch, as it looks at first sight, but represents the first leaf of the axillary branch, which does not ordinarily develop further than the bud stage. This too in FERONIA.

The leaf itself consists of two parts, a broad winged stalk and a blade, and at the junction of these two there is a sort of joint, a thing we never find in ordinary simple leaves.

Compare this now with the leaf of FERONIA, which has several leaflets attached to the winged rachis, by joints very much like this in appearance. If there were on FERONIA only one leaflet, it would be exactly like the leaf of the Orange. We conclude, therefore,

that the Orange leaf is not simple, but is really a compound leaf having only one leaflet.

The reason for this curious structure is a little difficult, but we can see that by the rachis being broadened and by the branches being green, the area of green tissue exposed to the light is increased so that more assimilation can be done, while being thicker and tougher in nature, the broad petiole is less likely to suffer in an extra day or hot wind, than would ordinary leaflets.

If the leaflet is held up against the light, a number of light spots will be seen. These are globular drops of oil (enclosed in special glands) which, being transparent, show white against the dark green tissue. The smell and bitter taste of this oil prevents animals eating the leaves, and the latter are also protected by thorns. But the axillary shoots here are not short, perhaps because the oil renders that unnecessary.

PARKINSONIA ACULEATA, L.

The branches are green, and have short stiff thorns, half an inch long. From the sides of these thorns spring (generally four) pinnate leaf-like organs. These have each a well marked pulvinus, a broad rachis, and numerous small elliptic leaflets. At the base of the thorn are two small marks or scars, and if we examine the youngest portion of the branch, we shall see that these are the scars of small pointed stipule-like scales. Just above the thorn is a small bud.

Since there is no leaf-scar just below the thorn, it cannot be of a branch nature, while the stipules on the sides and the minute bud in the axil, point to its

being a leaf. If it is a leaf, then the leaf-like organs which arise on it are pinnæ and not leaves, and this is confirmed by the fact that there are no buds in their axils, as there would be if the thorn were a branch, and they were really leaves. Compare PITHECOLOBIUM DULCE (p. 174).

If we examine this plant when new growth is taking place at the beginning of the hot weather, we shall find the spines, and the stipules also, soft and green. Sometimes the stipules do not fall off, but harden and become thorns like the main rachis. The very young pinnæ curve upwards at first with the minute leaflets folded flat along the upper side of the rachis.

The conversion of the main rachis of the leaf into a thorn, and the reduction in the size of the leaflets, is an adaptation to zerophytic, or dry land and air, conditions. Corresponding with the reduction in the size of the leaflets the rachises of the pinnæ have become broad, and being much harder and tougher than the leaflets, are not so liable to be dried up and withered by a hot wind. Notice too, that when a branch has been picked for some time, or while it is on the plant if the day be hot, the leaflets fold flat along the upper surface, their upper sides downwards.

A similar folding of the leaflets occurs in a number of plants with compound leaves, and further reference to it was made in chapter xiii. We cannot doubt that it is of a protective nature, serving to prevent the leaflets being scorched by the hot midday sun when the air is dry, or suffering when for any reason, the supply of water is diminished. A

similar movement at night appears to have for its object the protection of the green tissue against chill.

OPUNTIA DILLENII, Haw.

The Prickly-pear.

At first sight, this plant seems to be made on an utterly different plan from the ordinary. It has normal roots but the shoot instead of consisting of cylindrical stems and branches, with flat green leaves, seems to be made up of a number of very thick flat oval segments fixed end to end. These segments are studded with little areas, from which project numerous short barbed hairs (the fact that they remain so firmly stuck in the human skin shows that they are barbed) and one or two long yellow thorns. Occasionally on the uppermost segments, especially during rains, there are to be seen short thick green leaves, and, above each, one of these little thorny areas, which therefore are axillary to the leaves. These leaves soon fall off, so that most of the plant, and indeed the whole of the plant for much of the year, has no leaves at all. And this is why the stem is green—to make up for the absence of the leaves, and it is flattened for the same reason that leaves are flat, to expose the greater surface to the air and light.

Each segment of the shoot represents a portion of the axis, for the shoot does not grow straight in monopodial growth, but after a few weeks, the direct growth ceases, and is continued by a lateral branch. This is the reason for the segmentation of the shoot, and for the irregular way in which the segments are attached to each other.

The thorns may represent axillary branches, as they are in many other cases. But the barbed hairs appear to be a special structure peculiar to the family to which the Prickly-pear and Cactus belong. The spines, undoubtedly (as in the other cases cited) keep animals from eating the plant, for were it not for them, this luscious watery plant would soon be eaten by animals, during the hot dry months. But we cannot say that they have been developed with the purpose of keeping cattle from eating the shoot. Indeed all these spines and thorns that we have examined, are probably the direct result of the dryness of the air, as was said in the case of ZIZYPHUS and the Barberry.

ACACIA MELANOXYLON, R. Br.

The Black-wattle which is planted on hill stations and also occasionally on the plains.

This tree has alternate lanceolate or elliptic, slightly falcate leaves which stand stiffly upright.

There are three things about these leaves which at once strike a careful observer.

In the first place, they are utterly different from those of all other Acacias. In the White-wattle, ACACIA DEALBATA, for instance, the leaves are bipinnate with numerous small leaflets, and the same is true of all Indian Acacias—for example ACACIA ARABICA (fig. 43).

In the second place, these leaves have no marked midrib, but several veins which start from the base and curving out come together again at the tip—a basal venation which is rare among dicotyledons.

In the third place, one sees at once that if the stalk be not twisted, the plane of the leaf is not at right angles to

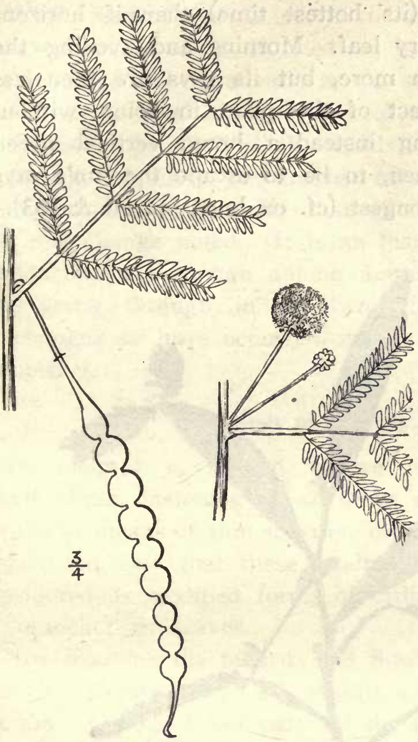

FIG. 43

ACACIA ARABICA, Willd.

the twig on which it is borne, as it is with all leaves, but passes through it. The explanation of these anomalies will be found on some of the shoots which spring from low down on the trunk in the deep shade of the upper foliage, or from the stump of a tree that has been cut down. There we find bipinnate leaves with small leaflets, and a broad petiole that shows exactly how the upper 'leaves' have been formed. We may find at every stage, leaves with several pairs of pinnæ and a slightly broadened petiole, to leaves with broad petiole and only two small pinnæ, and finally the broad red petiole alone without leaflets (fig. 44).

This broad petiole standing stiffly upright with its plane vertical, thereby catches less of the sun when

directly overhead (its hottest time) than if horizontal like an ordinary leaf. Morning and evening the leaf faces the sun more, but its rays are then less intense. The object of the plant in doing without leaflets and having instead a broad vertical green petiole appears, then, to be to escape the sun's rays when they are strongest (cf. on buds pp. 96 & 163).

FIG. 44

ACACIA MELANOXYLON, R. Br.

Young plant showing the change in the form of the leaves.

When seed of this Acacia is sown, the young plant always has after its cotyledons, small but normal bipinnate leaves. Gradually as the seedling grows the leaves that arise have in succession, smaller pinnæ and broader petioles, till the usual flat 'leaf' appears, after that no more pinnate leaves are formed. The seeds germinate so readily that some should be sown and this change noted. It is an instance of a phenomenon common enough among animals, of an individual going through in its own life the same sort of changes as have occurred in the evolution of the species.

Homology of tendrils

In chapter x, section 4, we learnt that many plants climb, fastening on to other sturdier trees and shrubs by means of thin sensitive organs called tendrils, and it was said that these tendrils are usually to be considered as modified forms of ordinary organs such as branches or leaves.

Now examine the tendrils and flowering parts of the ordinary ANTIGONON. The tendril is three-pronged at the top. On the lower parts of the plant it arises like a branch in the axil of a leaf, in the upper parts, it is obviously a continuation of the axis of an inflorescence (i.e. of an ordinary branch), and is homologous, therefore, with the end of a branch, or inflorescence-axis.

In the case of the PASSIFLORA, the Passion-flower, and many other plants, the whole of the axillary branch is modified as a tendril. In VITIS the Vine, etc., some of the tendrils stand opposite to the leaves, and in the axil of those leaves there is no bud. Hence the tendril

is really the continuation of the main axis, the apparent continuation being the axillary branch of that leaf—a case of sympodial growth.

In most cases the tendril is to be considered a modified leaf or part of a leaf, or leaflet.

In various species of BIGNONIA (fig. 23), this is easily seen to be the case, the leaf consisting obviously of two leaflets and a tendril. Occasionally, one may find one or more of the branches of the tendril expanded into blades, that is, reverted into leaflets.

In PISUM, the common Pea, the whole of the leaf is modified into a branched tendril, the branches corresponding to leaflets, and the functions of the leaf are undertaken by the very large stipules.

In GLORIA SUPERBA (fig. 22) the tip of the leaf is prolonged as a tendril.

In SMILAX outgrowths from the base of the leaf act as tendrils. These are sometimes said to be modified stipules, but as no others of the plants of that family possess stipules, it is better to consider them as special tendrilar outgrowths of the leaf-base.

In CUCUMIS, the Melon, Cucumber, etc. and other CUCURBITACEÆ, the tendril is partly a branch partly a leaf structure.

Emergencies

So far we have been studying plants with thorns, spines or other structure which by observation of their position and surroundings we must consider to be modified branches, stipules or parts of leaves. But there are many plants with structures to which we cannot assign in the same way the same morphological importance.

Thus examine branches of Rose, or TODDALIA ACULEATA, or LANTANA, or RUBUS. There are curved prickles on the branches and leaf stalks, but unlike those that we have studied, they seem to be in no particular arrangement, and are scattered without reference to the position of any other organ. We cannot therefore consider them as modified branches, stipules or anything else, but only as emergencies, that is, merely raised and hardened portions of the outer tissues. It is quite easy to remove one with a small piece of the cortex, for they have no connexion with the central part of the shoot, as have thorns that are modified branches.

The same is the case with the strong hard thorns that occur on the branches and stem of ERYTHRINA INDICA, and of BOMBAX MALABARICUM, the Silk-cotton tree.

They of course, serve the same function as other thorns—from the physiological point of view they have the same value, in homology they are utterly different, being, like hairs, outgrowths of the surface.

CHAPTER XVI

THE INFLORESCENCE

1. In some plants, as for instance, NELUMBIUM the Sacred-lotus, and NYMPHAEA the Water-lily, the flowers are borne singly on long leafless stalks which rise straight up out of the ground from the root-stock; in others again, there is a bunch or a head of flowers at the end of such a stalk, as in CRINUM, EUCHARIS the Eucharis lily, TARAXUM the Dandelion, and several other COMPOSITÆ, and in ERIOCAULON. Such a leafless flower stalk is termed a **scape.** It occurs as a rule only on plants which have no leafy stem, but merely an underground root stock or bulb from which the leaves and the scape spring.

Most plants, however, have leafy shoots above ground, and their flowers are borne on short stalks in the axils of the ordinary leaves, or on special branches, or at the ends of branches. The stalk of each individual flower is termed its **pedicel,** and if there is a main stalk to the pedicels of several flowers it is termed the **peduncle.**

The peduncle and the pedicel are to be considered as specialized branches, for they nearly always arise

in the axils of leaves, or of small thin scales called bracts, and these may be regarded as reduced leaves, since we may find every stage between real normal leaves and very small scale-like bracts even on the same plant, for example in GYNANDROPSIS and CLEOME (fig. 8, p. 43).

Just as there are two systems of branching in the vegetative parts, the monopodial and the sympodial systems, so also are there two main systems in the flowering parts, called respectively the **racemose** and the **cymose.**

2. In CLEOME, ERYTHRINA, CÆSALPINIA, POINCIANA the Gold-mohur, BRASSAIA NIGRA the common Mustard, and many other plants, the flowers are arranged on short pedicels, one after another along a main peduncle, which may continue to elongate indefinitely giving off branches (pedicels), as in the monopodial system of branching. This kind of inflorescence is termed a **raceme,** and in it we see that the oldest flowers are at the base, the younger nearer the top.

Of this racemose arrangement there are several different types, termed respectively:—

(i) The **corymb,** when the pedicels of the younger flowers are shorter than those of the older, so that the flowers themselves stand at about one level, and the bunch is more or less flat, as occurs in JATROPHA, GYNANDROPSIS (at least in the younger stages), and many other plants.

(ii) The **spike,** when there are no pedicels but the flowers are sessile on the main axis (peduncle), as in ACHYRANTHES (fig. 45) CELOSIA (Cock's comb), TRITICUM (Wheat), SORGHUM (Cholam) and others.

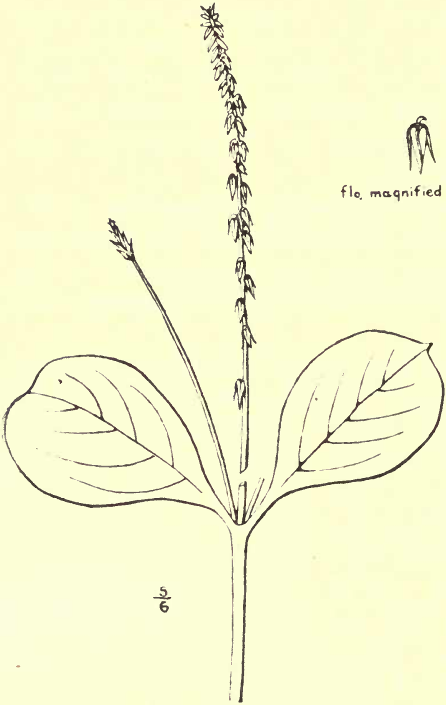

FIG. 45

ACHYRANTHES ASPERA, L.

(iii) The **spadix,** when the main axis is enlarged and fleshy, and the flowers are sunk in it, as in plants of the Arum family, ACORUS (Sweet-flag) CALLADIUM, etc. There is generally a large leaf-like organ called the **spathe,** which encircles and encloses the spadix at least before the flowers are matured. A spathe occurs on many plants which have not a spadix—in EUCHARIS, and CRINUM it is a thin brown papery thing which covers the flower buds at first, and hangs down untidily afterwards. In some palms it is extremely large being two or three feet long and quite thick, and in the Arum family it is often very gaily coloured. For instance, in CALLA ŒTHIOPICA (the so-called Arum-lily, which however, is not a Lily at all), it is large and white, and is the principal

ornament of the plant. In ARISÆMA (the Cobra-plant) it is marked with brown lines and bends over the spadix, in ANTHURIUM it is often a bright red colour.

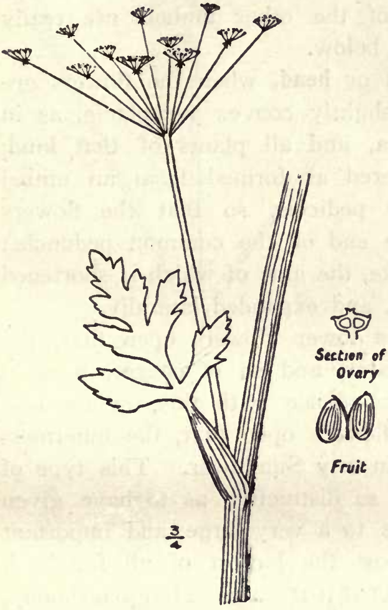

FIG. 46

HERACLEUM SPRENGELIANUM. W. & A.

(iv) The **umbel** when as in CRINUM, EUCHARIS, DÆMIA EXTENSA (fig. 58). HERACLEUM the Hemlock, PASTINACIA the Parsnip, CORIANDRUM the Coriander, and others, the pedicels spring from the same level, as if the internodes between them, i.e. of the peduncle were reduced to nothing (fig. 46). In CRINUM, EUCHARIS, AGAPANTHUS and other monocotyledons, the umbel is borne on a scape and is at first enclosed in a large spathe; in DÆMIA (fig. 58) and others of the ASCLEPIAD family, umbels occur short peduncles in the axils of the leaves of the shoot without any enclosing bract. In HERACLEUM, PASTINACEA and a number of other plants like them, there is a whorl of bracts at the point where the

pedicels spring, and the umbels are themselves collected into larger umbels. This type of inflorescence is so distinctive that the name UMBELLIFERÆ (umbel-bearing) has been given to the family to which these last belong. Some of the other umbels are really cymose in origin, see below.

(v) The **capitulum** or **head,** when the flowers are sessile on a flat or slightly convex receptacle, as in the Sunflower, Zinnia, and all plants of that kind. This may be considered as formed from an umbel by reduction of the pedicels, so that the flowers become sessile at the end of the common peduncle; or as a condensed spike, the axis of which is shortened almost to nothingness, and expanded laterally.

In the raceme the lower flowers open first, the upper and younger later, and so of course, it is in the spike. In correspondence with this, in the true head the outermost flowers open first, the innermost last, as can be seen in any Sunflower. This type of inflorescence is again so distinctive as to have given the name COMPOSITÆ to a very large and important family of plants (almost the largest of all families), which include EUPATORIUM the Hemp-agrimony, HELIANTHUS the Sunflower, COSMEA, GAILLARDIA, CHRYSANTHEMUM, GNAPHALIUM the Everlasting, CNICUS the Thistle, TARAXUM the Dandelion, SONCHUS the Sow-thistle, COREOPSIS and all plants like them.

Condensed inflorescences very similar in appearance to the capitulums of the COMPOSITÆ, occur in other families. The head of ERIOCAULON the Hat-pin plant of the hills, is composed like that of the COMPOSITÆ, of small flowers massed together with a common involucre

of green bracts below, but differs from the latter in that the individual flowers are perfect having well developed sepals. The Teazel, DIPSACUS, has also a head of flowers, with bracts below, just like that of the COMPOSITÆ, but the flowers open first in a ring about the middle of the spike, about half way between the centre of the head or summit of the spike, and the circumference or base, and it is therefore probably of a cymose nature really. The common Scabius, SCABIOSA, belongs to the same family.

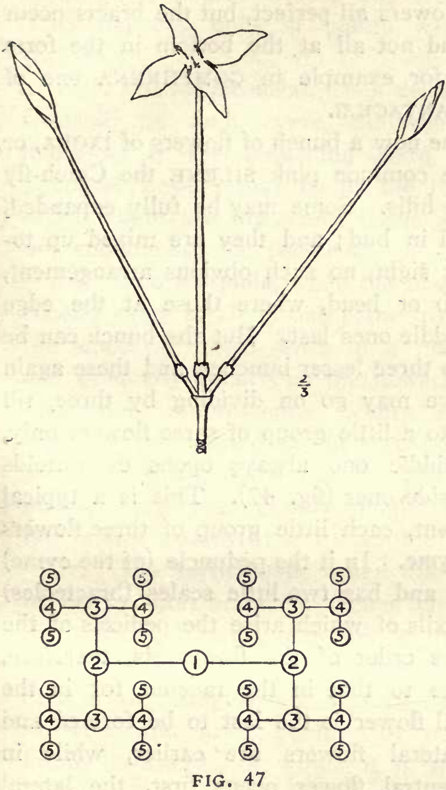

FIG. 47

A SINGLE CYME FROM A BUNCH OF IXORA FLOWERS

Below diagram showing the arrangement of the flowers. Numbers denote the order of development.

A typical DICHASIAL cyme.

In other cases the condensation is less complete, and not only are the flowers all perfect, but the bracts occur between them, and not all at the bottom in the form of an involucre, for example in GOMPHRENA one of the family AMARANTACEÆ.

3. But examine now a bunch of flowers of IXORA, or CINCHONA, or the common pink SILENE the Catch-fly of gardens on the hills. Some may be fully expanded, others still folded in bud; and they are mixed up together in, at first sight, no such obvious arrangement, as in the corymb or head, where those at the edge open first, the middle ones last. But the bunch can be easily divided into three lesser bunches, and these again into three, and we may go on dividing by three, till we come at last to a little group of three flowers only, of which the middle one always opens or unfolds earlier than the side ones (fig. 47). This is a typical cymose arrangement, each little group of three flowers being termed a **cyme.** In it the peduncle (of the cyme) ends in a flower, and has two little scales (bracteoles) on it, from the axils of which arise the pedicels of the side flowers. The order of the flowers is, therefore, the exact opposite to that in the raceme, for in the latter the terminal flower is the last to be formed and to open, the lateral flowers are earlier, while in the cyme the central flower opens first, the lateral after it.

Of cymose inflorescences there are also several types, termed respectively:—

(i) The **dichasial,** when the branches (pedicels) are in pairs as in IXORA, and CARISSA CARUNDAS, HYPERICUM JAPONICUM, etc. and each pair

is at right angles to the one from which it arose. This happens only in plants with opposite leaves (fig. 47).

(ii) The **monochasial,** when there is only one branch (pedicel) in each cyme, the whole then generally looks as if the branching were alternate, and the youngest flowers may be at the top as in a raceme, but if there are bracteoles these will be opposite to, not subtending, the pedicels.

(iii) The **scorpioid,** when the branching of the monochasial cyme is all in one plane, to right and left, and the whole is curled down in a plane at right angles, and gradually uncurls as the flowers open. This very distinctive inflorescence occurs in HELIOTROPIUM (fig. 36), the Heliotrope, in MYOSOTIS the Forget-me-not, in CYNOGLOSSUM the Hound's tongue, and in a number of other closely related plants belonging to the family BORAGINEÆ (p. 150).

(iv) The **verticillaster** when the flowers are massed in dense short-branched cymes on each side of the main shoot, forming together a thick ring, or false-whorl towards the ends of the branches. We find this in LEUCAS, MENTHA, LAMIUM the Dead-nettle, OCIMUM and in a number of other plants of the family LABIATÆ, of which it is the distinctive form of inflorescence. The cymose nature can best be made out in those cases where the bunches are loose as OCIMUM (Tulasee), SALVIA, SCUTELARIA the Skull-cap, the Lavender and COLEUS.

A cymose inflorescence may also take the form of an umbel, if the pedicels and peduncles are very short or absent altogether. This occurs in CRINUM,

AGAPANTHUS, EUCHARIS, and others of the same family, the AMARYLLIDACEÆ, and differs from the racemose (or true) umbel of the UMBELIFERÆ in that the flowers open one after another irregularly and not all together, or the outermost first.

The essential difference between inflorescences of a cymose and those of a racemose type, is that in the former, the axis always ends in a flower, the next flower being therefore on a side branch (arising in the axil of a bracteole); whereas, in those of the racemose type, there is a main axis which continues indefinitely bearing flowers along its whole length. We may call the cymose type therefore **definite,** the racemose **indefinite.**

4. Cases often occur in which the inflorescence is of a mixed character both cymose and racemose, or is too ill-defined to class in either category, for example:—

The **fascicle,** when a bunch of flowers occur on the main axis, with more or less equal pedicels all sessile on the axis, like a sessile umbel. A fascicle may really be racemose or cymose in nature, but as a rule it is impossible to say in which class it should be placed. The common garden flower, ANTIGONON, has small fascicles of two or three flowers in the axils of bracts along a leafless branch (which ends in the tendril). The cymose character of the fascicle is here clearly shown by the difference in the size of the buds, and the order in which they open.

The **panicle**—a compound inflorescence, that is, one in which the main axis is branched, is termed a panicle. The ordinary panicle is a branched raceme, but a

branched spike is also called a panicle (fig. 14 of AGAVE).

In some cases the main axis is branched racemosely and has on the branches small cymes of flowers, as in ÆSCULUS, the Horse-chestnut. It is then sometimes called a **thyrsus**, but this along with other compound inflorescences may be called simply a panicle.

CHAPTER XVII

ON FLOWERS

1. Examine a flower of CÆSALPINIA PULCHERRIMA or of POINCIANA REGIA the Gold-mohur or Flame-of-the-forest (of some), which are planted all over India in gardens and by road sides, or if these are not available take a CASSIA, e.g. CASSIA AURICULATA the Tanner's Cassia, or CASSIA TOMENTOSA the common yellow flowered bush of the hill-stations, or CASSIA FISTULA the Indian Laburnum.

The flowers are borne on stalks (pedicels) one above another on a long central axis, the end of a branch. The pedicel is slightly enlarged at the top, and if we examine the flower, we find it consists of a number of different parts arranged in circles. First there are five **sepals**, which spring smoothly from the dilated top of the pedicel. In CÆSALPINIA, they are red in colour and four of them are obovate in shape, the remaining one being curved and hollowed out like a spoon. Before the flower opens, when it is still a bud, the sepals cover and enclose all the rest, the largest, spoon-shaped, sepal being outermost of all.

Above and inside the sepals are five **petals.** These stand between the sepals, alternating with them, and

are larger and more brightly coloured than the sepals. They constitute indeed, the glory and the beauty of the flower. In CÆSALPINIA and in POINCIANA, four are broadly obovate in shape with a narrow stalk, or **claw,** while the fifth is smaller, and curled up into a tube with a spreading top.

Inside these and attached to the edge of the top of the pedicel which is slightly hollowed in the centre, is a ring of ten **stamens.**

In CÆSALPINIA and in POINCIANA, the stamens are red and very long and stick out considerably beyond the petals, while in some species of CASSIA, some are long and curved and others much shorter and straight. At the end of each is a small, or in CASSIA a very large and long, oval-shaped body, the **anther,** in which are two slits and in these are seen tiny golden yellow grains. The anther is a sort of box, or rather a pair of boxes side by side full of this yellow powder —termed **pollen**—and in POINCIANA, CÆSALPINIA and most other plants, opens by slits, but sometimes by holes at the ends as in CASSIA and Brinjal, to let the pollen out.

The stalk of the anther is termed the **filament,** and may be very long as in CÆSALPINIA, or shorter than the anthers, as in CASSIA.

In the centre of the flower, is a green oblong body, attached by a very short stalk to the bottom of the hollow at the end of the pedicel, and extending upwards in a long (in CÆSALPINIA red) **style.** The end of the style is a little flat fringed spot, termed the **stigma.**

If we open the green oblong part, by running a needle along one edge, we shall find that it is hollow,

and that inside, along the edge which is posterior or uppermost in the flower, are attached a row of tiny greenish-white bodies. These subsequently become the seeds, and are called **ovules,** the whole hollow box being the **ovary.**

Now if we examine a number of flowers of either of these kinds, we shall always find the same parts and the same numbers. There are always in the plants mentioned, five sepals, inside and alternating with the sepals, five petals, inside these again a ring of stamens; and an ovary with its style and stigma in the middle. After a few days, the sepals, petals, and stamens fall off and die, leaving only the ovary, which grows very much larger, till from being from one-third or half-inch in length it becomes, in CÆSALPINIA, two or three inches long and nearly half an inch wide. In POINCIANA it grows still more, becoming twelve or eighteen inches long and one and a half to two inches wide. It is now termed the **fruit,** and when quite ripe is hard and dry, and splitting open along the two edges allows the **seeds** to fall out.

In CÆSALPINIA there are six to eight seeds in each fruit, and they are attached by short stalks **(funicles)** to one (the **upper** or **posterior**) edge. The seeds we know will, under suitable conditions, germinate and grow into new plants, the rest of the fruit after hanging on the tree for a while, drops off and decays. So that the seeds are the only really permanent part, and the whole purpose of the flower appears to be (and really *is*) accomplished with the ripening of its seeds.

Now looking at the whole bunch (inflorescence) we see that the pedicels all slope upwards and outwards

from the central axis, so that the flowers face upwards and outwards. We find too that in CÆSALPINIA and POINCIANA, the largest (the curved spoon-shaped) sepal stands always on the lower and outer side, and the smallest (in CÆSALPINIA tubular) petal stands exactly opposite it on the upper and inner side. Or if we imagine ourselves in the flower, facing like it outwards, we may call the upper, inner side, the back or **posterior** side, the lower, outer side, the front or **anterior.**

We learn then that these flowers have not only a definite number of parts, but also a definite **posterior** and **anterior** side, the former being the upper and nearest the central axis, the latter the lower and furthest from it.

If there were only one flower, facing directly upwards at the end of an upright single stem, it would have no back or front, all the sides being similar. This is the case for instance with the Sacred-lotus and other Water-lilies.

2. Now take a flowering branch of ERYTHRINA INDICA. The flowers are borne, on short pedicels one above the other along an upright axis, so that the first to open are the bottom ones, the youngest being at the top. The arrangement is the same as in CÆSALPINIA, POINCIANA, and most CASSIAS, and is a raceme. Each flower is at first enclosed in a green covering, which splits open as the flower unfolds and takes the place of the separate sepals of CÆSALPINIA. As in the latter, the flowers when fully open, face side ways, away from the main axis. The most conspicuous part of each flower is the

large red petal which stands on the upper—or posterior—side, and in bud wraps round the others. Under and in front of it, are two much smaller petals, and these in their turn enclose two others which are on the forward or anterior and lower side (since the flower faces horizontally). The arrangement of the petals as seen from above when the bud is cut across is something like this (fig. 48).

FIG. 48
DIAGRAM OF PETALS OF ERYTHRINA

In the centre of the flower is the narrow oblong ovary, a thin hollow box in which is a row of ovules, and which extends upwards in a long thin style. Round the ovary is a tube split open on the upper or posterior side and divided at the end into nine filaments each with an anther. In the open space so formed lies a stamen with its anther.

We may consider the flower as having ten stamens, of which nine are joined together into a tube which is not complete because the tenth stamen is free. When this arrangement occurs the stamens are said to be **diadelphous.** When all the rest of the flower has fallen off, the ovary lengthens into a long cylindrical fruit, slightly constricted between the seeds.

3. Now examine in the same way the flowers of CROTALARIA JUNCEA the Sunn-hemp, PHASEOLUS the Bean, DOLICHOS the Lablab, PISUM the Pea, LATHYRUS the Sweet-pea or any other of that kind.

Each flower is enclosed at first by five green sepals, arranged as in CÆSALPINIA, one on the lower, anterior side, and two other pairs.

Inside the sepals, are five petals, which as in the other plants, are attached to the top of the pedicel, and between (that is, alternating with) the sepals. The largest petal, and the first to unfold, because it in bud wraps round the others, is the posterior or uppermost, just as in ERYTHRINA. Under this are two oblong petals, and under these again a pair which are broad about the middle and narrowed towards the tips, and are connected together to form a boat-shaped organ ending in a narrow tube.

This pointed structure, formed by the union of the two anterior petals, is termed the **keel,** the two lateral oblong petals are called the **wings,** and the uppermost, large, posterior petal, the **standard.**

Lying inside the keel, and springing like the sepals and petals from the top of the pedicel, is a tube, which in CROTALARIA divides at the end into ten anther-bearing filaments. This tube may be considered as formed of ten stamens joined together, and they are for this reason said to be **monadelphous.** In the other plants mentioned, the tube is incomplete, one filament being free as in ERYTHRINA, that is, the stamens are **diadelphous.**

In CROTALARIA, too, the anthers are not all alike, five being long and narrow, the other (alternating) five almost globular in shape. But in practically all other plants, the anthers are all alike.

Inside the staminal tube, lies the ovary, which, like that of CÆSALPINIA and ERYTHRINA, is a hollow case containing one row of ovules attached to the upper, posterior side, and ending in a curved style. On the style are a few hairs pointing upwards, and the extreme tip is the small oval stigma.

After a while the sepals and petals fall off, the ovary expands and splits the staminal tube, (which also withers away), and finally becomes the fruit. This is cylindrical, but slightly flattened on the upper side, and contains the seeds, plainly attached to the upper edge by short funicles. Examine a good many flowers of these, and other kinds, and notice that in all the flowers of any one kind the number and shapes and arrangements of the petals is always the same. Flowers therefore are definitely arranged structures, not haphazard collections of coloured parts.

And comparing the flowers that we have studied, we find that there are certain resemblances and certain differences. In all we find the same kinds of parts,—sepals, petals, stamens (with anthers) and ovary (with ovules). These parts are the **organs** of the flower, and nearly every flower contains them all, though in some, one or another is not developed. The most important of them are, as we shall see later, not the conspicuous gaily coloured petals, but the comparatively insignificant looking stamens and ovary.

In other respects, too, the particular flowers studied, are alike. The sepals, petals and stamens are in 5's,—5, 5 and 10, and the ovary consists of a hollow chamber with the ovules attached along one (the upper, posterior) edge.

In all of them, too, the sepals and petals are arranged in two pairs with one odd. The odd sepal is always the lowest (anterior), the other four being symmetrically arranged; and the odd petal is in the same way always the uppermost (posterior). But there is this difference, that whereas with POINCIANA, CÆSALPINIA and

CASSIA, this odd (posterior) petal is innermost of all in bud, with ERYTHRINA, CROTALARIA, and the others, it is outermost of all, and is much larger than the others.

The arrangement of the petals (or any parts) in bud, is termed the **æstivation,** and into it we will go more fully later on.

CHAPTER XVIII

THE CALYX

1. If we open one of the smaller buds of CÆSALPINIA, GYNANDROPSIS, or almost any plant, we shall find the anthers and ovary fairly well developed, but the petals much less so and comparatively small.

In such cases the entire duty of protecting the anthers and ovary devolves on the sepals, which when their work is done with the opening of the flower, generally fall off. They are usually green or brown in colour, and thicker than the petals, and this, of course, increases their protective power.

In many plants the place of the sepals is taken partly or wholly by a cup-shaped organ called the **calyx** (calyx = cup), which has generally along its upper margin, lobes or teeth corresponding to sepals, and may be considered as made up of sepals joined together at the base. In HIBISCUS, GOSSYPIUM (the cotton plant) THESPESIA, and many other plants, the calyx is almost or quite entire, and therefore open at the top, so that it cannot completely enclose the other organs except when they are very small. But if we examine buds of these plants, we shall find that the

petals are much bigger than in the other cases, and thicker and rather hairy at the top, where they are exposed beyond the calyx. In these cases the anthers and ovary are protected partly by the petals. In GOSSYPIUM, the cotton plant, there are three large green leaf-like organs (bracteoles) attached to the pedicel just below the calyx, and these stand up and enclose the bud, but spread out as the flower opens. In THESPESIA there are also three bracteoles, but these are small and fall off sometime before the flower opens, and we should notice that, in correspondence with this, the ends of the petals are thicker than they are in GOSSYPIUM. We find the same sort of thing in some species of LEUCAS, where the calyx teeth are short and the upper lip of the corolla is very hairy.

Again in the COMPOSITÆ (the Sunflowers, etc.), and in the DIPSACACEÆ (the Teazels, and Scabius), the flowers are protected in the early stages by the bracts of the involucre, and the calyx teeth are reduced to mere hairs.

2. On the other hand, the petals are in some cases absent and their place taken by sepals which are then very large and brightly coloured, just like petals, as happens, for instance, in ANEMONE. We say that it is the petals and not the sepals that are absent in this case, because we have agreed to call the outermost circle of floral organs sepals, and where they are undeveloped there is always a ring or something else to show it. It is only another instance of what we have already learnt in our study of seeds, thorns and tendrils—that, in determining the nature of an organ, we must go, not by its appearance, which

depending as it does on its function, may be different from the normal, but by its position on the plant in relation to other organs.

In many cases the sepals or calyx are coloured although the corolla is present, as, for instance, in DELPHINIUM, the Monk's hood, MICHELIA the Champaca, TROPÆOLUM the Garden-nasturtium, CÆSALPINIA PULCHERRIMA, CASSIA FISTULA the Indian Laburnum, BEGONIA, HOLMSKIOLDIA, PETRÆA, and many other common Indian plants. They then add to the beauty and attractiveness of the flower, which is the chief duty of the petals (see chapter xxi, section 3).

This is even more the case with MUSSÆNDA, a very common shrub on the ghats and hills of South India, up to 6,000 ft. One sepal of the five here grows out like a large white leaf (this is one sign of the leafy nature of sepals), and shows up the dark orange corolla of the corolla very clearly.

In the case of BOUGAINVILLÆA, the colour of the flower is due to three bracts, which belong each to one of the three small tubular flowers inside, for these flowers have no petals, the perianth being single—a tubular calyx only.

3. In a very large number of plants the calyx tube or cup, surrounds the ovary and is even produced beyond it, and bears at the top the petals and stamens. The ovary thus stands below the latter and is, therefore, said to be **inferior**. We can hardly in this case consider the calyx tube as made up of combined sepals, but rather as the deeply hollowed out end of the pedicel, the ovary being in the middle and therefore at the bottom

of the hollow. For sepals are structures of the nature of leaves (though without buds in their axils), and leaves do not have other organs growing out of them.

In a few plants the hollow at the end of the pedicel is but shallow, so that the calyx stands only half way up the ovary. The stamens and petals then stand round, not on top of the latter, and may be called **perigynous** (peri = round), or the ovary **half-inferior.**

4. There are other considerable differences in the sepals or calyx of different plants. The main purpose being in most cases the protection of the young parts, when the flower has opened, the sepals often fall off. Thus in ARGEMONE, PAPAVER (poppy) and others of that family, the calyx forms a hood over the flower and is pushed off entire by the developing petals. In DATURA the top half is pushed off in this way, the lower only remaining.

In other plants the sepals persist as long as the petals, and even remain on the fruit, as in the Guava. PHYSALIS, the Cape-gooseberry, is peculiar in that the calyx becomes larger and forms a sort of red bladder round the fruit.

CHAPTER XIX

THE COROLLA

1. The Corolla is in nearly all flowers the most conspicuously coloured and beautiful part (in a few it is the calyx that is coloured, and again several plants have no corolla or only a small dull green or yellowish one). It may consist of 3, 4, 5, or 6, separate petals, as in BERBERIS the Barberry, and ANONA SQUMOSA the Custard-apple, in CLEOME (fig. 8) and MATHIOLA the Stock, in the Rose, the Guava and the Mango or in ANONA RETICULATA the Bullock's heart. There may be a short or long tubular part below with 3 to 6 lobes (or petals) at the free end, as in PHLOX, SOLANUM the Brinjal and Potato plants, SESAMUM the Gingelly plant, ANTIRRHINUM the Snapdragon, etc. The lobes (petals) may be very long as in STROPHANTHUS, or very short, or even quite absent as in CONVOLVULUS and IPOMÆA where the corolla is all one entire bell or funnel shaped organ.

In the first case it is termed **polypetalous** (literally meaning many petalled), in the second **monopetalous** (meaning one petalled), or **sympetalous** (meaning that it

looks as if the petals were joined together somehow at the base).

2. But in any case whether monopetalous or polypetalous, the shape is described as—

regular, if of a general circular form, e.g. a flat plate as in Brinjal, or a funnel-shaped tube as in CONVOLVULUS, so that it could be divided into perfectly symmetrical and similar parts in any direction through the axis.

irregular if one side (generally the lower or the upper side) is larger than the other, so that it could be divided into two equal halves only in one plane through the axis (generally from back to front).

3. The shape of the corolla, or of the calyx, is further described as—

stellate, if flat with pointed lobes or petals like the conventional rays of a star, as in the corolla of the Brinjal, Chilli, etc.

tubular, if cylindrical of about the same width throughout, as the corolla of SESAMUM and RUSSELIA.

campanulate if narrow at the base but soon widening with straight sides, like an inverted round bottle with a very short neck, or like an old fashioned or a Japanese or Burmese bell, as the corolla of CUSCUTA CHINENSIS the Dodder, and the Canterbury-bell.

trumpet-shaped, if narrow at the base and widening gradually like the end of an oboe or trumpet or like an ordinary modern bell, as the corolla of IPOMÆA and CONVOLVULUS.

salver-shaped, if with a narrow tubular part which spreads out sharply and widely at the top, as the corollas of VINCA, the Periwinkle, CERBERA ODOLLUM.

urceolate, if of a companulate shape but the mouth contracted, and of smaller diameter than the rest, as the corolla of ERICA the Heather, and VACCINIUM the Bilberry, and GAULTHERIA.

There are many cases, of course, in which the shape cannot be described so simply, and a combination of these terms, or some further explanation is necessary. Thus the corolla of TABERNÆMONTANA CORONARIA, is described as 'salver-shaped, the tube slender, inflated at the middle'. In such a flower the places at which such sudden broadening or inflation of the tube occurs is termed the **throat**, the open end of the corolla being its **mouth**.

In some flowers it may be more convenient to describe the petals separately from the corolla, when the same terms are used as for the leaves (chapter xii, sec. 2).

IRREGULAR FLOWERS

4. All irregular flowers bend over slightly so that the posterior side is also the upper and the anterior side the lower, and these terms are used even more than posterior and anterior.

The plane of symmetry is nearly always through the axis (pedicel) and peduncle, from posterior to anterior, not from right to left, the posterior or upper side being larger or smaller than the anterior or lower, but the right and left halves exactly similar. Only in a very few is the plane of symmetry across from right to left—in FUMARIA (Fumitory), CORYDALIS, CYCLAMEN and others of that family. And in still fewer the plane of symmetry is neither, but oblique (MALPIGHIACEÆ, SOLANACEÆ).

In some cases the irregularity is due to a petal or a sepal being projected downwards as a short or long tube. If about as long as broad, this projecting tube is termed a **sac**, if several times as long or broad, a **spur.**

In TROPÆOLUM the Garden-nasturtium, and in IMPATIENS the Balsam, the lower sepal is **spurred**, projecting downwards in a pointed tube an inch and a half or so long. If the flower-stalk (pedicel) of PELARGONIUM the Garden-geraneum be cut across, a narrow tube will be found in it on the anterior side. This is equivalent to the spur of TROPOÆLUM or IMPATIENS, the tubular part of the sepal having become fused with—or **confluent** with—the pedicel.

In VIOLA the Violet and Pansy, and in IONIDIUM, the anterior petal is produced back as a short sac, in which lie two backward projections from the two anterior stamens (see Part II). In many Orchids too, the lower petal is **spurred** or is **saccate.**

5. But in most cases of irregular flowers there is no spur or sac, only the lower petal sare of a different shape to the upper. In some, the lower petals (or the part of the monopetalous corolla which corresponds to them) hang down broad and flat, like a tongue, and is termed a **lip.** The upper petals are generally arched, the whole flower being sometimes like a mouth, with an **upper** and a **lower lip.** Such flowers are termed **two-lipped.** There is one family of plants, in which the flowers are mostly of this kind—i.e. distinctly two-lipped. It is therefore called the LABIATÆ or 'lip-family'.

The ordinary Sunflower again, consists of a number of small **florets** massed together in a head, most

of which are tubular, but in the outermost ones the whole corolla is extended as a long yellow flat tongue. Such florets or flowers are termed **ligulate** (tongued), for there is no upper lip. The same is the case in Zinnia, while in the Chrysanthemum and Dandelion all the florets are ligulate.

At first sight there may not seem to be much difference between a lip and a ligule. But the word lip (or **labellum** sometimes) is used when a part only of the corolla is so extended while part forms an upper lip, ligule, when the whole is expanded on one side, so that there is no upper lip.

THE ÆSTIVATION

6. On examining flowers of different plants, we soon find that there are differences not only in the number and shape of the parts, but in the way in which the petals are folded together in the bud.

We have already seen that in CASSIA and in POINCIANA the posterior petal is innermost, while in CROTALARIA and PHASEOLUS, it is outermost. Each plant, or rather each family or group of plants has its own method of folding the petals, and the peculiar mode in each case is termed its æstivation.

In some the petals (or corolla lobes) just touch by their edges, and do not overlap each other at all. They are then said to be **valvate.**

In others each overlaps the next on one side, being in turn overlapped by the one next it on the other. The petals then generally slope to one or the other side, the whole bud appearing for this reason to be twisted. They are then said to be **convolute** or **twisted**.

This is the case with HIBISCUS, GOSSYPIUM, ALTHÆA the Hollyhock, and all others of that family, with VINCA, CERBERA, NERIUM, PLUMERIA (fig. 27) and all others of their family, with JASMINUM, and with the Coffee, IXORA (fig. 47) and many other plants.

In a very large number of plants, the petals (or corolla lobes) overlap each other unequally, one or two being overlapped by two edges, and one or two overlapping the next ones, by two edges. They are then said to be **imbricate**. This is the arrangement in CASSIA, CÆSALPINIA, PISUM the Pea, LATHYRUS the Sweet-pea, and the other flowers studied in chapter xvi.

We have seen too that with this there is the further variation, that in the first two the odd posterior petal is innermost of all in bud, in the other two, it is outermost (fig. 48, p. 202).

In many cases the corolla is folded inwards along (generally) five lines, which run up the flower from the base. This is well seen in SOLANUM and DATURA when the areas left in bud exposed to the light, are of a slightly lighter shade, and appear in the opened flowers as five lens-shaped areas. This type is known as **induplicate.**

In IPOMŒA and CONVOLVULUS and others of that family the corolla is folded in the same way, but also twisted—and may be distinguished from the last as **induplicate-convolute.** The same occurs in GENTIANA the Gentian.

CHAPTER XX

THE STAMENS

1. Next inside the petals (or corolla) there stand in nearly all flowers one or more circles of stamens. The normal and complete stamen consists, as we have already learnt, of a sort of double box, **the anther** supported on a long or short **filament,** the tissue joining the two halves of the anther and connecting them with the filament being called the **connective**.

2. Now we find among plants very considerable differences in their number and character, and in the exact positions they take up in the flower, though they are always inside the petals, and outside the ovary —greater differences indeed than in the case of the sepals or petals.

But if we examine a number of flowers on the same plant, or on different plants of the same kind, we shall find the stamens (just as we did the petals), alike in all, so that their nature is of some importance in aiding one in the determination of the species to which a plant belongs. Not only is so, but the general nature of the stamens is usually the same for all the species of a genus.

3. In some genera the stamens are so numerous that it is impossible to tell at a glance how many there are, and the number probably is slightly different in different flowers. This is the case in the Lotus and Water-lily (family NYMPHÆACEÆ) in NARAVELIA and CLEMATIS, in MICHELIA, in POLYALTHIA, CANANGA, and ANONA the Custard-apple (family ANONACEÆ) in PAPAVER the Poppy, and ARGEMONE (family PAPAVERACEÆ), in CRATÆVA (figs. 10 and 18) and in many other species belonging to these and other families.

4. But in most cases the number is the same as or double that of the petals or the sepals, or one or two less, so that it is easily counted and is quite definite. When the number is the same as that of the petals or corolla lobes, the stamens stand usually opposite the spaces between them—opposite, that is, to the sepals. This is the case, for instance, in IXORA, VINCA, SOLANUM the Brinjal and Potato plants, and a host of other genera.

We shall easily understand the advantage of this arrangement if we consider that all the parts are rather crowded together in the bud, and that there will be more room in the spaces between the petals than immediately above them. When the number of stamens is double that of the petals, as in QUISQUALIS the Rangoon-creeper, they can be considered as being, and as a rule obviously are, in two whorls, of which the outer is opposite the sepals, the inner alternating with them and opposite the petals.

In a few families, however, the stamens are of the same number as the petals and yet stand opposite

to them. This is the case, for instance, with ZIZYPHUS the Jujube, RHAMNUS the English Buckthorn, COLUBRINA and all others of the family RHAMNEÆ, where the petals being deeply curved or hood-shaped, enclose them in the early stages before the flowers are fully opened.

Sometimes too when there are two circles of stamens, the outer stand opposite the petals and the inner opposite the sepals, instead of the other way about. This is the case with the GERANEUM and OXALIS family, but is not easy to make out in these flowers.

In by far the majority of cases, however, if there is one circle of stamens equal in number to the petals, they stand alternately with them, and if there is a second whorl inside, the members of it stand alternately again with those of the first and therefore opposite to the petals.

In a very few families we find, three or even four circles of stamens as in BERBERIS (petals three, stamens twelve) and in PHŒBE, CINNAMOMUM, LITSÆA and other LAURINEÆ (petals three, stamens twelve).

5. In a large number of families especially those with monopetalous corollas, the stamens are fewer in number than the corolla lobes. In MILLINGTONIA the Indian Cork-tree, in KIGELIA the Sausage-tree, BIGNONIA commonly grown in gardens and in SPATHODEA there are five lobes to the corolla, and alternating with them only four perfect stamens, but there is a small projection standing where the fifth should be, and obviously representing the fifth in an

aborted or rudimentary state, while the Tamarind has only three, and two bristles. In other families, e.g. in the ACANTHACEÆ LABIATÆ, VERBENACEÆ SCROPHULARIACEÆ, there are only four stamens with no trace at all, as a rule, of a fifth, but the four that do occur are in the same places, as they would be if the whole five were present. In BARLERIA (one of the ACANTHACEÆ) two of the four stamens are much smaller than the other two and have no pollen, and there is a gap where the fifth stamen might have been, opposite the uppermost sepal.

In JUSTICIA and in ADHATODA, belonging to the same family, there are only two stamens with no trace whatever of the other three. We must suppose that in these cases the whole number five is unnecessary, and that only four or two, as the case may be, are developed, to save material.

When a stamen is without anther or pollen, being therefore sterile and undeveloped, it is termed a **staminode.** Staminodes occur in many families, among polypetalae as well as synpetalae. Sometimes they are mere points, in other cases they are broad and coloured like petals. The commonest Indian example of this is CANNA. In this flower there are three short sepals just above the ovary, three-coloured petals, and in the middle of the flower a flat style and a flat stamen with part of an anther on one edge. The other structures between the petals and this anther are staminodes, and are usually coloured more gaily than the petals. The same is true of the flower of the ginger plant, ZINZIBER, of Cardomoms, MARANTA and others like them (see Part II). The

short point, which represents a fifth stamen, which stands on the upper side of the corolla tube, in the flowers of MILLINGTONIA, the Indian Cork tree, of KIGELIA the Sausage-tree, BIGNONIA, SPATHODEA the Flame-tree and many others is also a staminode.

The corolla of ACHRAS SAPOTA, the Sapodilla, is monopetalous with six or eight lobes. Alternating with these are an equal number of white scales. These also are staminodes.

In many unisexual flowers, where an ovary is developed, the stamens are represented by staminodes (and where the stamens are developed, the ovary is represented by a pistilode).

6. The stamens are often slightly connected at the base, but this connexion may extend all the way up the filaments, so that they form together a tube, to the top or sides of which the anthers are attached by their connectives. This is the case, for instance, in KLEINHOVIA one of the STERCULIACEÆ, where the anthers are in five groups of three each, in GUAZUMA where there are in addition five short points (staminodes) between the five groups. In MELIA the Neem, there are ten anthers, sessile or the top of the tube, the connectives being extremely short. In HIBISCUS, GOSSYPIUM and other MALVACEÆ, the anthers are very numerous, and attached not merely to the top but along the sides, too, of the tube by long connectives.

In RICINUS the Castor-oil plant, the filaments are divided (branched) and have an anther at the end of each branch, so that there are more anthers than filaments. In BOMBAX the Silk-Cotton-tree, the filaments are joined at the base into five bundles which

stand alternately with the five petals. Each bundle we may suppose therefore to be due to the splitting of one stamen. The same thing occurs in HYPERICUM the St. John's wort, a bush very common on the higher mountains of South India, while in ERIODENDRON each filament is again divided at the top and has three anthers. In several other cases though not in obviously distinct bundles, the stamens are shown by their development to have been derived by the splitting of an original few. This, for instance, is the origin of the two pairs of long stamens in the Stock and Wallflower family (CRUCIFERÆ).

7. We may think, therefore, of stamens as occurring in four principal ways:—

(1) Numerous and indefinite in number.

(2) Definite in number, and equal to or double or treble the petals. Free or connected (monadelphous, etc.).

(3) Fewer in number by the non-development of one or more.

(4) Very numerous because derived by the splitting of a few, and then separate, or joined together into one or more bundles.

THE CONNECTIVE AND ANTHER

8. The **anther,** as we have seen, contains numerous tiny round grains of **pollen,** and is attached to the filament connected by a tissue called the **connective.** In most cases this tissue is barely visible except at the top, but when the two halves of the anther are separated, as sometimes occurs, it is easily made out and in some species of SALVIA (Sage) it may be half an inch long, with the two halves of the anther, at either

end. In some families the connective is continued beyond the top of the anther as a flap or cover to it. In ARTABOTRYS, ANONA the Custard-apple, and other genera of the family of ANONACEÆ, it forms a flat top to the anther. In IONIDIUM and in VIOLA the Violet, it is like a thin brown scale (flap) as also in the Sunflower, in COSMEA and in plants like them.

9. We have already learnt that in some cases the filaments are connected together, it may be—as in the case of HIBISCUS and THESPESIA—into a complete tube, but the anthers were in these always separate. There is, however, one very important family of plants —the COMPOSITÆ—which have among other characters, this in common, that the filaments of the stamen are separate (free) while the anthers are connected, and form a sort of hollow tube through which the style runs up. Anthers connected in this way are termed **syngenesious.**

This can be easily seen in the Sunflower. If you look at a flower-head that has been open a day or two, you will find, perhaps, the central florets unopened —then round them others showing brown anthers with small brown flaps and at the top of these a small quantity of yellow pollen grains. Towards the periphery there will be no pollen, but sticking out from the top of anthers, the two branches of the style. In a day or two those in the centre will have opened while the ring of florets with styles showing will be broader. Thus as the floret matures, the style pushes through the box formed by the anther and ultimately coming out at the top, divides into the two stigmas.

Syngenesious anthers also occur in LOBELIA and others of another family the CAMPANULACEÆ, which are not included in the COMPOSITÆ, because their flowers are not aggregated in heads in the same way.

In CUCURBITA, CUCUMIS MELO the Melon, and others of the family CUCURBITACEÆ both the filaments and the anthers are joined together into one mass which occupies the centre of the flower. (The ovary with its style occurs on separate flowers, not with the stamens.) In some genera of this family, the anthers appear to be doubled back on themselves in a S shape. And in the ASCLEPIADACEÆ, they are not only fused all together but also connected to the top of the styles.

10. The two halves of the anther are usually exactly equal in size, and together form one two-lobed anther. In JUSTICIA, ADHATODA, and a few others, one half of the anther stands a little lower down on the filament than the other, and has a white appendage, or tail, at the base.

In MILLINGTONIA the Indian Cork-tree, in KIGELIA the Sausage-tree, in TECOMA and in others of the family BIGNONIACEÆ, the two halves of the anther are connected to the filament at the same level, but diverge widely to right and left.

In SALVIA, the two halves are completely separated, and in some species the lower half is sterile, containing no pollen. It may, indeed, be flattened and quite different in shape from the other upper half, so that only the existence of transition species, in which both halves are fertile, shows definitely that it is really a deformed or rudimentary anther-lobe, and that the

connexion between the two is really the enormously developed connective.

THE ANTHER

11. As an anther develops there are formed inside it four hollow spaces, side by side, two in each lobe. These can be seen quite easily with the naked eye, in large anthers like those of CRINUM KIGELIA or PASSIFLORA, if the sepals and petals be removed from a young flower-bud a day or two before it would naturally open, and the anthers be cut across with a very sharp knife or razor.

Inside these four spaces, there are produced a number of tiny spherical bodies (true cells) which can be seen only with a microscope, and inside each of these cells, there are again formed four others still smaller. These grow larger and become the grains of pollen. So that the pollen grains are at first, at any rate, in sets of four.

In time the four spaces, which since in them are developed the pollen grains, are called **pollen sacs** coalesce into two, so that in the mature anther we find only two, one in each lobe. These spaces are sometimes called **cells.**

In by far the greater number of plants, the two cells open along two lines, and so set free the pollen, which is then scattered by the wind or taken away by the bees, butterflies, and other insects that can always be found hovering about flowers on a warm sunny morning.

In a few cases only, does the pollen escape from one slit, the two cells becoming confluent into one.

In some genera, the cells open through round holes or pores at the top (or bottom) of the anther. These pores are very obvious in SOLANUM the Brinjal, Chilli, etc., in RHODODENDRON and in some species of CASSIA.

In two families the LAURINEÆ and the BERBERIDEÆ, there are holes on the sides of the anthers, and these are covered by little flaps which open and close like doors.

THE POLLEN

12. The pollen grains are formed, as was said above, in sets of four, and when ripe fill the whole hollow space of the anther, as a mass of tiny golden balls. In some species the pollen grains are smooth, in others they are covered with small warts or spines, and tend to stick together. It is a curious fact of which we shall see the connexion further on, that in small and inconspicuous and scentless flowers, like those of grasses, Paddy, Ragi, etc., the pollen grains are smooth, while in large showy flowers like Hibiscus they are usually spiny or rough (see p. 234).

In some species they are connected together in sets of four, the sets in which they were formed. In others again the sets all cohere together in one mass, and when the anther opens come out as such. This is the case in ALLAMANDA. There are two important families the ASCLEPIADACEÆ, and the ORCHIDACEÆ, in which the pollen grains of each anther cell are nearly always united into a single mass, which is then termed a **pollinium.** We shall study these later on, when dealing with the plants themselves (see Part II).

CHAPTER XXI

THE OVARY

1. The centre of the flower is usually occupied, as we saw it was in CÆSALPINIA, etc., by the ovary. At the top of the ovary is a slender rod, the **style,** and this ends in a small or large, sticky, part or the **stigma.**

The ovary itself is a case, either completely hollow or divided up into compartments, **cells.** That of CÆSALPINIA or POINCIANA, for instance is 'one-celled', that of GOSSYPIUM the Cotton plant, nearly always three-celled, of HIBISCUS five-celled. Inside the ovary, the seeds are attached walls along one or more slightly thickened ridges, called **placentas.**

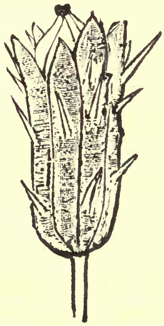

FIG. 49
FRUIT OF ARGEMONE MEXICANA

If these are on the outer wall of the ovary as in IONIDIUM, PAPAVER the Poppy, ARGEMONE, or CUCUMIS the Cucumber, the arrangement or placentation of the seeds is said to be **parietal.**

If, on the other hand, the seeds are attached to the inner angles of the cells (or to the central column in which the partitions of the ovary meet), the placentation is termed **axile.** Axile placentation occurs in most families, in practically all those in which the ovary has more than one cell, e.g. in GOSSYPIUM, HIBISCUS, CITRUS the Orange, and PYRUS the Pear and Apple.

In two or three families, the ovary consists of but one cell with a large central placenta which is not attached to the wall. This is termed a **free central placenta.** In others there is only one seed and that is attached to the base of the ovary, as in the common ANTIGONON, and the Docks. This placentation is termed **basal.** The Water-lilies (NYMPHÆACEÆ) are peculiar in that the seeds are not arranged on placentas but scattered all over the inside of the cells.

THE STYLE AND STIGMA

2. In CÆSALPINIA the style rises from the top of the ovary, not quite in the middle, but (as can be seen best in young fruits) from nearer the upper edge, and curves slightly upwards and backwards, ending abruptly in a slightly sticky part—the stigma. In the ordinary HIBISCUS, or Shoe-flower which is grown in gardens, the style rises up quite centrally from the top of the five-celled ovary, and divides at the end into five branches, each with a fairly large round velvetty ball—its stigma. In Hypericum and in Biophytum there are five styles while in GYNANDROPSIS, CLEOME, and CRATÆVA (figs. 8 and 10), and in ARGEMONE and PAPAVER there is no style at all, the stigma resting (sessile) on the top of the ovary.

Again in the last two generas the stigma is very large and in the form of five or more brown hairy ridges radiating from the centre towards the edge of the ovary. In TORENIA the stigma is a curiously hollow-folded structure, which closes up if touched, and in RICINUS there are three long red stigmas.

So that there is very considerable variety in the forms of the style and stigma. As a rule, the number of branches into which the style divides, or of stigmas, or at any rate of the lobes of the stigma, corresponds to the number of cells in the ovary, or if the ovary is one-celled to the number of parietal placentas.

This however is not by any means always the case. The ovary of the Sunflower is one-celled, but its style branches into two stigmas. The ovary of GYNANDROPSIS is one-celled but its stigma has two lobes. That of PAVONIA has five cells but ten stigmas.

In some genera as OCIMUM, Tulasī, the ovary is not arched at the top but hollowed, and the style rises from the base of the hollow not from the highest point of the ovary.

But for the different kinds of style and stigma reference must be made to the actual flowers themselves.

THEORETICAL CONCEPTION OF THE STRUCTURE OF THE OVARY

3. In CÆSALPINIA, POINCIANA, CASSIA and the Pea, the ovary is one-celled and the seeds or ovules are arranged along one (the upper) side. We noticed, too, that the ovary is not symmetrical in the plane of its width, the style rising rather from one side.

Now examine the ovary of STERCULIA, SIDA, GERANIUM or OXALIS. When the fruit is ripe it splits apart into its five (in MALPIGHIA three) cells, and to each cell is attached a style (or part of the style). In each there are one or more seeds, so that each corresponds to the whole ovary of CÆSALPINIA. We may indeed look on the ovary of these plants as being made up of units, of which in CÆSALPINIA there is only one, in MALPIGHIA three, in GOSSYPIUM three, and in SIDA, STERCULIA, OXALIS, IMPATIENS and GERANIUM five. This unit is named a **carpel**, and is here, and in most flowers, a closed organ, having ovules arranged inside on a placenta, along one edge, and more or less prolonged outside upward into a style. When several carpels compose the ovary, they are united by their placental edges.

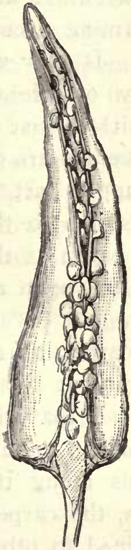

FIG. 50
Fruit of CAPSICUM the Chilli cut open

Cut open an ordinary Chilli fruit we find that it is two-celled at the base, and one-celled at the top and the placentas to which the seeds are attached, are on either side of the partition in the lower part, but on the sides of the fruit in the upper (fig. 50).

We may explain this on the hypothesis that the ovary is composed of two carpels, by supposing the carpels to be quite closed in their lower half, but open along their placental edges in the upper.

We have here the result of the union in the lower half of the fruit, of two completely closed carpels—forming a two-celled ovary with axile placentas; and in the upper half of two open carpels—forming a one-celled ovary with two parietal placentas. If now we examine a fruit of the Poppy, Pappaw or Melon, we shall find that the ovary (and the fruit) consist of but one cell, not several, and that the placentas are on the outer wall, just as they are in the upper part of the Chilli fruit. So that, if the latter is due to the carpels not forming a completely closed organ at the top, in these it must be because they are open all the way down.

We come then to the conception of a carpel, as an organ which has seeds on two placentas running along two edges, and which usually is folded so that the two edges and their placentas meet, and in many-celled ovaries is joined to other carpels along the same lines. And that in one-celled ovaries, the carpels are not closed, but are nearly flat and joined to other carpels along the placental edges, the placentas fusing in pairs and forming as many lines of seeds, as there are of constituent carpels.

4. In POINCIANA and all plants like it, the style rises from the edge furthest from the placenta, and is as it were a continuation of it, and where an ovary has several cells, i.e. is made of several carpels, the style is in the same way a combination of the styles of the carpels. We may see various stages of this combination in VINCA, where the carpels are separate but share one style, in AVERRHOA BILIMBI, and many others, where there are five styles to the five-celled

ovary, in HIBISCUS, etc., where the style divides into five branches, corresponding to the five cells of the ovary, and in CITRUS the Orange flower, where there are many cells but only one undivided style. Since in compound, or **syncarpous,** ovaries the carpels are arranged in a closed circle at the centre of the flower, the style, compounded of their separate styles, is centrally placed at the top, and we can understand why on this hypothesis it is eccentric on one-carpelled ovaries and central on those of many carpels. We can indeed generally distinguish at a glance between a one-carpelled ovary such as that of CÆSALPINIA, Pea, Gram or Mango, and a SYNCARPOUS one-celled ovary like those of the Violet, Poppy, Pappaw or Melon, because of this difference in the position of the style.

CHAPTER XXII

POLLINATION

1. We will now inquire into the functions and uses of the various parts of the flower, by the aid of simple experiments that any one can do.

If we remove from a newly opened flower the calyx and corolla, taking care not to damage the ovary or stamen, we shall in nearly every case, find that the seeds form and ripen just as in flowers which have not been mutilated. But if before the flower opens, we cut out the stamens, or remove the anthers whole without breaking them, we shall probably find that no seeds are formed. If now after removing the anthers we touch the stigma with an anther of another flower of the same plant, so that some of the pollen adheres to it, seed will be formed and ripen just as well as if the flower had been left intact. From this we may conclude, that neither sepals nor petals have any direct effect on the formation of seed, but that it is absolutely necessary that pollen should be put on the stigma. If the experiments described above be done carelessly, the anthers may easily be broken and some of their pollen be left on the stigma,

but if done with care it will always result as described. One may make more certain of it by covering the flower with a small paper bag.

The Palm which gives the edible date fruit, has flowers of two kinds, borne on different palms. The plants that is to say are **diœcious,** one kind having only ovary flowers which ripen into the fruits, the other only staminate flowers which do not produce fruit. Many hundred years ago it was known to the Arabs and to cultivators of Egypt, that the ovary flowers would not produce fruits unless branches of the staminate flowers, when newly opened and shedding pollen, were placed near them. From this there arose a religious ceremony in which flowering branches of the staminate palms were placed (or waved sometimes with suitable incantations), so that the yellow pollen dust might fall on the newly opened ovary flowers. What exactly is the nature of pollen and how it causes the formation of the seed and fruit, is now known to science. If we put a few pollen grains in a solution containing about 3% of sugar (the exact amount differs with different flowers) and examine them in the course of a day or two with a good lens, we shall find that from most of the grains fine threads, which are really very narrow tubes, have grown out. This is what happens on the stigma. The pollen grains are caught on the sticky sugary surface, and the tubes growing out in the same way, pass downwards through the style and into the ovary, and there each makes its way to the micropyle of an ovule, into which it discharges part of its contents (two 'nuclei') and then, but not till then, the ovule starts to become the seed.

2. Pollen then is required to fertilize the ovules Now it is a curious fact, which we cannot exactly explain, though it has been proved in many cases, that seeds formed by ovules fertilized with pollen from the same flower, do not develop into such fine and healthy plants, as do those fertilized by pollen from a different plant of the same species. So that the carrying of pollen from flower to flower is good for the seed produced.

In nature, pollen is taken from one flower to another to a certain extent by wind, but in most cases by small animals, especially flying insects, which are attracted by the bright colour and the sweet scent of the flowers, and come to suck the honey so often found at the base of the petals, or to eat or carry away the pollen. Bees, for instance, carry away and store in their nests for future consumption, large quantities of pollen, while Butterflies and Moths suck the sweet liquid which is produced at the bottom of most flowers. In doing this they inadvertently carry away pollen grains on their legs, head, wings or other parts of the body, and leave them on the sticky stigma of some other flower. This explains what was said in chapter xx, section 12, that pollen grains of small inconspicuous flowers are usually smooth, those of large or sweetly scented flowers, spiny or sticky. Spiny or sticky grains would adhere to the legs and bodies of insects much better than would smooth grains, and, as a rule, insects visit only gaily coloured or scented flowers.

By patient observation and experiment, it has been found that in any flower almost every detail of shape

and colour has to do with the fertilization of its ovules, and in general to discourage pollination from its own anthers, and encourage that from other flowers (of the same species), though self-fertilization is often provided for in case the other fails.

Thus the stigma and anthers usually come to maturity at different times the former being in wind-fertilized plants the first to ripen, and the last in those visited by insects, as may be seen in the flower head of a Sunflower (see Part II).

Wind-fertilized flowers differ also from those which depend on the visits of insects, in having, as a rule, light powdery pollen, which is easily carried by the breeze, and long feathery styles. This is the case with SORGHUM, Wheat and other grasses.

In many animal pollinated flowers the object appears to be to discourage all but a particular class of insect or bird. Thus some flowers are adapted specially for the visits of long-tongued insects (butterflies and moths), their long tubular corollas preventing smaller insects reaching the honey that lies at the bottom. Others are flat so that the honey is freely exposed, and are visited mostly by flies and beetles with short tongues. Some flowers are closed in, and can be opened only by clever or heavy bodied insects, such as bees. This is the case with the Pea and other PAPILIONACEÆ, with ANTIRRHINUM (the Snapdragon) and many others. Flowers which open at night, like MILLINGTONIA (the Indian Cork-tree) and IPOMŒA BONA-NOX (the Moon-flower) are usually white, and have heavy sweet scents, so as to be easily found by night-flying moths. Others again have like ARISTOLOCHIA

emit a most disagreeable small, and attract carrion-feeding flies. Large red flowers, like HIBISCUS, are in their native country visited by small honey-sucking birds, and there is one plant whose flowers lie exposed on the ground and are probably pollinated by snails, while some of the most curious and wonderful of all adaptations are found in the flowers of Orchids. But we cannot go more fully into the matter till we have studied plants more, and learnt more about them.

3. These, then, are the functions of the different parts, the ovary produces the seeds, but can do so only if fertilized by pollen, which is formed in the anthers. The corolla because of its bright colour is the conspicuous part of the flower and with the help of the often sweetly-scented honey formed at its base, attracts insects, or birds, which bring pollen from other plants so that the resulting seeds have stronger embryos. And all these delicate parts are, while being formed in the bud, covered and protected by the sepals or calyx, whose place however is often taken by other parts (in the Cotton plant by the bracteoles, in the Sunflower by the involucre), as is sometimes that of the corolla by the stamens in THALICTRUM and CANNA, or by the sepals, in ANEMONE, etc.

Since the general shape and colour of a flower may be special adaptations to attract some special class of insect, they are not of much importance as criteria of a plant's relationship. The union or non-union of the petals, the number of the stamens, the superior or inferior position of the ovary, and the number of its cells, are far less likely to be affected, and are

therefore of much greater value for the scientific arrangement of the genera in their families. But for this see Part II, and especially the concluding chapter.

CHAPTER XXIII

THE FRUIT

1. When all the rest of the flower of CÆSALPINIA has fallen there remains the ovary, and this grows to many times its size, and contains the seeds. It is then known botanically as the **fruit.** In common speech we usually mean by fruit, the part of the flower which has grown and become edible, and which we eat, like a mango, orange, grape or brinjal, but in botanical language by fruit is meant any part of the flower or of its stalk that developing after the flower has faded contains the seeds—whether it be edible or not.

In some cases the fruit when the seeds are fully formed is dry and brittle, and opens in some way or other so that the seeds may drop out, as is the case with Cotton, Balsam and Pea. In others, the fruit is soft, and whether it contains one or more seeds does not open, but remains on the tree entire until it drops off to the ground and there rots away, or, as is more likely, is eaten by animals. These fruits (which do not open) are termed **indehiscent fruits,** to distinguish them from **dehiscent fruits,** which open naturally.

Fruits that have a soft or pulpy part (generally edible) like the mango, guava, melon, are termed

fleshy fruits, and are practically always indehiscent. Those on the other hand, which are hard and woody (and not usually eaten by human beings except when quite young and soft) are termed **dry fruits.** Most dry fruits contain several seeds and are **dehiscent,** like those of CÆSALPINIA, but there are many which do not open. Nearly all of these have but one seed inside, like PONGAMIA, PTEROLOBIAM, or the so called 'seed' of the Sunflower.

FIG. 51

FOLLICLES OF CRYPTOSTEGIA GRANDIFLORA, Br.

DEHISCENT FRUITS

2. There are several kinds of dry dehiscent fruits.

In the Pea, Bean, Gram, CÆSALPINIA, CASSIA, PITHECOLOBIUM and others like them, the ovary is one-celled with one row of seeds, and when ripe opens along two edges. This kind of fruit is termed a **legume.** It occurs only in the members of a large family, called on that account the LEGUMINOSEÆ. In MICHELIA, DELPHINIUM, STERCULIA, CALOTROPIS, VINCA and other genera belonging to their families, the ovary consists of several cells or units, which (at any rate in fruit) are not combined, but quite separate, and each contains, one

row of seeds like the legume, but open along one edge only. To distinguish it from the legume, this unit is termed a **follicle.** In MICHELIA and DELPHINIUM the fruit consists of several follicles, in STERCULIA URENS of five, in CALOTROPIS of one, because the other does not develop, in others of the family ASCLEPIADACEÆ, and in VINCA, NERIUM and PLUMERIA the Pagoda and Frangipanni, of two.

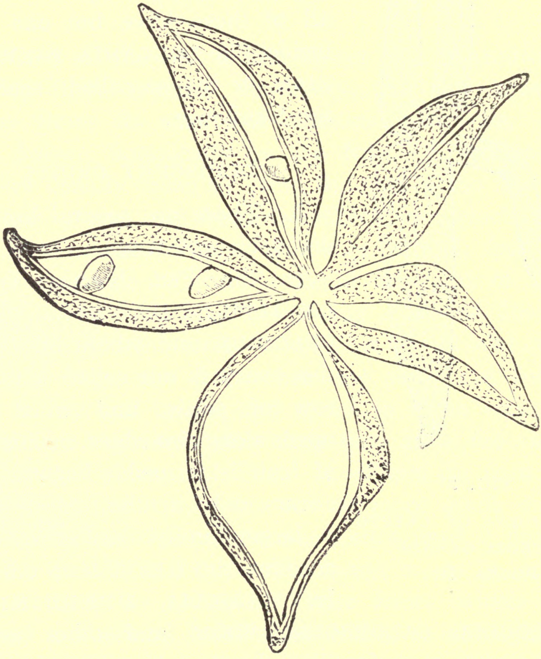

FIG. 52

FRUIT OF STERCULIA URENS, Roxb.

Again in ABUTILON (fig. 31, p. 146) SIDA, ALTHÆA the Hollyhock, in CORIANDER, in HELIOTROPIUM and nearly all of the family BORAGINACEÆ, in LEUCAS, SALVIA, and all of the family LABIATÆ, the fruit when ripe, separates into one-seeded parts which do not open further, and looking very like seeds, are generally in common speech called seeds. Inspection, however, will show that, though there is a scar like a hilum, there is no micropyle. This kind of fruit is called a **schizocarp**—which means splitting-fruit. In some cases the number of separated parts corresponds to the number of cells in the ovary, in others they are more numerous. A peculiar kind of schizocarp occurs in ÆSCHYNOMENE, DESMODIUM, MIMOSA and some others of the family LEGUMINOSEÆ, where though the ovary is one-celled, the fruit is divided transversely into one-seeded parts. This special type is sometimes called a **lomentum.** In ACER the fruit, a schizocarp, divides into two or three one-seeded parts, each provided with a flat extension (or wing), and called a **samara.**

But in PAPAVER, GOSSYPIUM, HIBISCUS, VIOLA, IONIDIUM, ADHATODA, and a very large number of other genera, the fruit does not separate into one-seeded parts, but opens as a whole, and is termed a **capsule.** When, as in the cotton plant, the capsule opens by the outer wall splitting down between the placentas or between the partitions, so as to open out the cells which may also separate at the inner angles, it is termed a **loculicidal capsule** (fig. 53), and this is the commonest kind. When the fruit opens by the breaking of the partition walls, so that the cells come

16

free of the central axis, which remains standing, it is called a **septifragal capsule.** And when the cells come quite free of each other, but do not split open at the back, so as to appear like so many follicles, the fruit is a **septicidal capsule** (fig. 54).

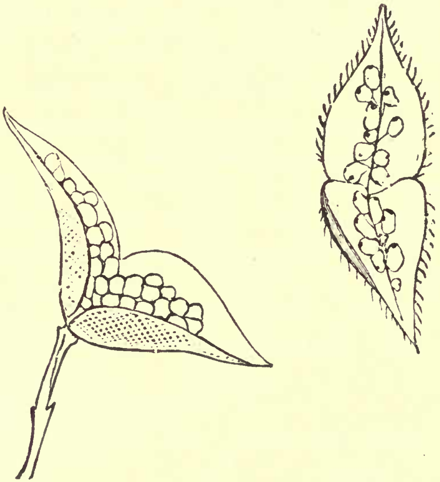

FIG. 53. FRUIT OF BIXA ORELLANA, L.

There are also other ways in which capsules open, it may be by a slit, **pyxis,** or by holes at the top, as in the Poppy, or by the top coming off like a lid as in TRIANTHEMA, and EUCALYPTUS or quite irregularly as in IPOMÆA BILOBA and THESPESIA POPULNEA.

INDEHISCENT FRUITS

3. Of indehiscent fruits there are two main types the **dry,** and the **fleshy** (or sometimes **woody).**

The ordinary dry indehiscent fruit is termed an **achene** or **nut.** In practically all cases it contains one seed only, and in common speech is usually called a seed; such are the fruits of HELIANTHUS the Sunflower, Cosmos and all others of the family COMPOSITÆ, and NARAVELIA, CLEMATIS, RANUNCULUS and also the so called seeds on the Strawberry fruit. The **grains** of Paddy, Sorghum, Ragi and other cereal plants are also achenes. In VENTILAGO the nut is winged and is termed a samara (a word used for both a winged nut and a winged part of a schizocarp).

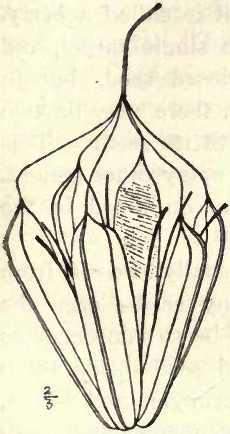

FIG. 54
FRUIT OF ARISTOLOCHIA

FLESHY FRUITS

4. By a fleshy fruit, we mean one of which the outer part is soft and juicy, and can be eaten by men or other animals. There are two main types of fleshy fruit. The Mango and the Apricot are fleshy fruits in which we can distinguish four parts, an outermost skin, a juicy part, a hard stone, and inside the latter the kernel. The kernel is the seed proper, everything outside it is developed from the ovary, for if we examine the stone of a mango or of an apricot we shall find no trace at all of the micropyle which every seed must have. This kind of fruit is called a **drupe.**

On the other hand, in the Grape (the raisin and black currant are dried grapes), the Brinjal, Chilli,

Guava and Melon, we can distinguish only three parts, an outer thin or thick skin, a juicy flesh, and the numerous seeds. This kind of fruit is called a **berry.**

The typical drupe is formed of a single carpel, and has only one stone with its enclosed seed, but in those formed of syncarpous ovaries, there may be two or more stones or **pyrenes** each with its seed. This occurs in ZIZYPHUS, LANTANA and many other genera. In a few cases there is more than one seed in the stone, but this is not common.

A berry, on the other hand, is usually derived from a syncarpous ovary and has many seeds, e.g. the Grape and Melon. But one-seeded berries do occur as the Litchee and the date, the hard seed inside these fruits being a true seed, with micropyle, and hilum, not a stone like that of the apricot, mango and coconut. In some cases the septa or inner walls of the ovary develop into scarious or leathery partitions between or round the seeds, such as the 'parchment' round the seeds in the coffee-berry, and the date, and the partitions of the orange and pomegranate.

Whether the fruit is a berry or a drupe, the outer-skin is called the **epi-carp,** the juicy portion, the **flesh,** or **meso-carp,** and the leathery or stoney coverings to the seeds, the stone or **endocarp.** While all these structures being formed from the ovary itself and not from the seeds, are collectively termed the **fruit-wall** or **pericarp.**

Special forms of drupes or berries are often called by special names. Thus in the case of the apple and pear, the ovary is sunk in the pedicel which therefore forms part of the fruit. The endocarp too

is very leathery. This special kind of berry is sometimes called a **pome.** Again the melon and cucumber have thick rind, and the juiciness of the mesocarp is due to the placentas (which become very large and watery). This fruit is sometimes called a **pepo.** In the Orange, on the other hand, the juiciness is due to the formation of juicy hairs between the seeds, while in the Litchee the fleshiness of the berry is due to the aril which grows on and surrounds the seed.

Again the Custard-apple and the Bullock's-heart (ANONA) consist of a number of separate fleshy carpels each with a seed, and is thus an **aggregate** of berries. The Raspberry and Bramble (RUBUS), consist also of a number of fleshy carpels, but each has inside it a stone or pyrene enclosing a seed, so that the fruit is an **aggregate** of drupes. The fruit of the Strawberry consists of a fleshy thalamus with a number of achenes or nuts on it. That of ANACARDIUM the Cashew-nut, is a fleshy pedicel with only one nut on it.

In all these cases the fruit as one sees it, is produced from one flower. But in MORINDA and in the fig and Jak-fruit trees, a large number of flowers grow so close together that they form one mass, and the resulting fruit is the product, not of one but of many flowers. To distinguish this kind of fruit from the aggregate berries or drupes of the Custard-apple or the bramble, it is termed a **collective** fleshy fruit.

In some cases the fruit is more or less fleshy till nearly ripe and then becomes dry or woody. Thus the separate carpels of MICHELIA are fleshy at first

but become dry and open later as follicles. The fruit of CERBERA ODOLLAM looks at first like a fleshy drupe, but the mesocarp dries up into a network of woody fibres between which there is only air, so that till the epicarp has rotted away, the whole fruit is much lighter than water and floats readily. The same is the case with the Coconut which is really not a nut proper, but a drupe with a fibrous mesocarp. It is probably due to this peculiarity that both these plants are found widely distributed along seabeaches in the tropics, their fruits being carried by the sea from place to place.

The foregoing are the principal kinds of fruit found among plants. There are, of course, variations of these for which special names have been invented, but it will be really quite sufficient for our purpose, if we are able to determine rightly to what type a fruit belongs, without troubling ourselves about the name of the special variation.

We must, however, notice that all the fruits of any one species, are of the same type and behave in the same way.

Schizocarps and capsules, drupes and berries are never found on the same plant, nor on different plants of the same species, still less are fleshy and dry fruits. The kind of fruit and the way in which it opens is as much a characteristic of the species as are the shape or nature of its leaves. Further, as explained in chapter xii, we usually group together into a genus, species which being somewhat similar in other respects are also alike in their flowers and fruit, so that the type of fruit is also characteristic

of the genus. In most cases all the genera of a natural order or family, are also alike in the type of fruit, but in some of the orders (e.g. RUBIACEÆ) different types occur.

CHAPTER XXIV

THE OVULE AND SEED

1. In their young undeveloped stage seeds are termed **ovules.** It is only after fertilization by pollen that an ovule will develop into a seed, but during this development very great changes in the structure of the ovule take place, and it may grow to be a hundred times its original size.

The ovule arises as an outgrowth of the placenta, and is at first an oval body, called the **nucellus.** Over the nucellus there grow first one, then (in some cases) another skin, the **integuments,** which beginning at the placental basal end, grow till they cover the nucellus except for a small hole at the further end. This hole is called the **micropyle** and is really of great importance to the seed (see p. 64).

As the ovule develops into the seed, these integuments become thicker and, when the seed is ripe, form usually a firm tough covering—the **seed coat** or **testa.**

At the base of the ovule there is developed a short or long stalk, the **funicle,** connecting it with the

placenta. The nature of the stalk differs to a certain extent, in different species—it is very short in the Bean and very long in some species of Acacia, such as the ACACIA DEALBATA and ACACIA MELANOXYLON which have been introduced from Australia to some of the mountains of South India. In RUELLIA, ADHATODA, STROBILANTHES, and other genera of the family ACANTHACEÆ, the stalks become very hard and when the pod opens, spring up elastically and jerk the seeds out. But in most cases the stalk is just the connecting link between the ovule and the placenta, and after the seed has matured is of no particular importance at all.

The **hilum,** we have already learnt, is the scar left on the seed when it was attached to the stalk.

Only in a very few species does the ovule develop straight, so that the seed stands straight out from the placenta. When it does so, it is called **ortho** or **straight,** and we find such seeds in ANTIGONON and others of the family POLYGONACEÆ.

In most cases the ovule as it grows becomes bent back on its stalk so that the further end (where the micropyle is) comes to be nearest to the placenta. It is then said to be **anatropous.** Such seeds occur in the greater number of families—instances are the GERANIACEÆ (Balsams) the EUPHORBIACEÆ (Castors) the Orchids and the Lilies.

Sometimes the ovule becomes not only bent back on its stalk, but curved also—as in the bean, gram and all leguminous plants, in HIBISCUS and other MALVACEÆ, in CHENOPODIUM and in the AMARANTACEÆ. It is then termed **campylotropous** and is

easily distinguished from ortho or anatropous seeds, because of the bent, curved embryo inside.

If we examine an ovary, we shall find that (except in a very few cases) all the ovules are of the same kind, and are all borne in the same way, mixtures of ortho, anatropous and campylotropous seeds never occur, and we shall in nearly every case find all the seeds sticking out at right angles to the placenta, or all hanging down (**pendulous**) or all standing up (**erect**).

Both ortho and anatropous ovules may be pendulous or erect. In the pendulous position, ortho seeds have the micropyle facing upwards, in the erect position downwards. With anatropous and campylotropous seed, it is of course the other way about, for the micropyle is at the basal end of the seed near the placenta. As but few genera have ortho seeds, it is usually sufficient to know whether the micropyle faces upwards or downwards.

In the case of anatropous and campylotropous seeds, as the ovule develops, the nucellus becomes fused to its stalk for that part of it along which it is bent back, the ridge so formed being the **raphe** (p. 48). According as the ridge is on the side next to or away from the placenta, it is termed a **ventral**—or **dorsal**—raphe.

Upon a little consideration it will be clear that erect ovules with dorsal, and pendulous ovules with ventral raphes, are much alike, and differ only in being pendulous or erect. Erect ovules with ventral raphes, and pendulous ones with dorsal raphes, are also much alike and different from the first pair.

2. The testa is nearly always firm and tough. In some cases, as in the Beans, it is particularly tough and almost waterproof. In the Castor it is, on the other hand, very hard and smooth and has peculiar markings on it. In ARGEMONE and others of the Poppy family, it is rough (pitted) in other cases it is wrinkled. In some cases it becomes slimy and sticky when wetted, e.g. in RUELLIA, PLANTAGO (sometimes used on this account as a cure for dysentery) and LINUM (flax). In the MALVACEÆ it is often covered all over with fine hairs (e.g. cotton) in others hair develops only from one end. This we shall refer to later on.

In addition to the two integuments which cover the whole seed, and become its seed-coat or testa, there develops on the seed of some species, another outgrowth from the basal end. This which is termed the **aril**, is different from the seed-coat proper, in being usually soft (fleshy) and in not covering the whole seed. On young seeds of PITHECOLOBIUM DULCE (korukapulai), for instance, it grows irregularly over the seed and is yellowish white in colour. In MYRISTICA, the Nutmeg, it is red and forms a very conspicuous irregular coating to the seed.

In NYMPHÆA, the Water lily, the covering is almost complete, while in the Litchi fruit, what we eat is the thick fleshy aril that covers the whole seed (underneath the brittle pericarp). An aril of some kind or another occurs in many species of the families SAPINDACEÆ and CELASTRINEÆ, in POLYGALA ARILLATA (of the hills), and in other plants. The seed of RICINUS, the Castor, has a small hard aril (sometimes called the caruncle) near the micropyle.

The small triangular swelling on the seed of the Bean, at one end of its hilum, represents an aril in a very rudimentary state. It is sometimes called the strophiole (p. 49).

3. As the ovule develops there is formed in it a hollow space, really a gigantic cell called the **embryo sac,** which gradually increases in size till it occupies the whole seed, the nucellus being literally consumed by it. Only in a few cases, e.g. in NYMPHÆA the Water lily, ARGEMONE the yellow Mexican Poppy, and PIPER the Pepper, does this not happen. In these, some of the nucellus remains in the ripe seed (comprises indeed most of it) and then is called **perisperm.**

Inside this embryo sac there develops the embryo, but before it matures the space is filled with a translucent soft substance, which from its likeness to moderately boiled white of egg has been named **albumen.** We must not, however, confuse it with real albumen which is a very different substance.

In some species the albumen gradually becomes dense and hard as the seed ripens, so that the ripe seed contains only it and the embryo which lies in it or round it. It is then called **endosperm** and such seeds are termed **albuminous** or **endospermous.** The Castor-seed is a familiar example of this.

In other cases the albumen disappears, being literally consumed by the growing embryo (just as the nucellus was by the embryo sac) which eventually comes to fill the whole embryo sac, and hence the whole of the seed. This is the case with the Melon, Bean, Pea and Gram. Such seeds are termed **exendospermous,** or more simply, as seeds without endosperm.

We never find some ripe seeds of a plant with endosperm and some without, nor some plants of a species with endospermous seeds others with exendospermous seeds. The different genera of a family are also usually alike, though they sometimes differ in this respect. It is important, therefore, in the determination of a plant to know whether the seeds are endospermous or not.

It must be remembered that, before the seed is mature, there is nearly always some albumen to be found, for that is always formed in the first instance. Where seeds differ is in the disappearance of this albumen on being consumed by the growing embryo, or in its persistence as endosperm.

There are differences, too, in the nature of the endosperm.

In the Castor-seed, it is **oily**—oil is got from it by pressure, and we have already learnt (p. 56) that practically the whole seed consists of endosperm.

In Paddy, Sorghum, Maize, Wheat, Ragi and other grains the endosperm is **mealy** or **farinaceous,** i.e. can be ground into a flour or meal. This is because it consists mostly of dry starch.

In the Date and other palms, it is very hard like horn (**horny**), and in the Coconut it is both horny and oily. In some species of MALVACEÆ it swells up and becomes slimy if wetted, and is said to be **mucilaginous** or gummy, and in one variety of Maize—the American 'Sugar Corn'—it is sugary.

There are often other substances in the endosperm besides the main one; thus the Castor-seed contains nitrogenous substances, and a poisonous alkaloid (ricin)

besides the oil. The outermost layer of the endosperm of Wheat, Oats, Paddy, Ragi and Sorghum is very nitrogenous and important therefore as food.

Where there is no endosperm the cotyledons often contain much oil (cotton-seed) or nitrogenous matter (Beans and other pulses) which make the seeds of great economic value.

It is worthy of notice that where the endosperm, or the cotyledons (as the case may be) are soft or contain food useful to animals (as in the Castor, Gram, Bean, Sunflower and Cereals) the covering of the seed is hard or tough, but where as in the Date and Coffee it is horny, the seed coat is thin and papery.

In some cases the inner testa is folded into the endosperm, which then appears to be marked by thick straight or curly lines, projecting inwards from the sides. This is very well seen in the fruit of ARECA, the Betel nut, the seed of ANONA the Custard-apple, and of MYRISTICA the Nutmeg. The endosperm is then said to be **ruminate.**

In all these respects, all the plants of any one species are alike, but not necessarily all the genera of a family, though this too is most often the case.

CHAPTER XXV

DISTRIBUTION OF SEEDS AND PLANTS

1. The seeds of many plants have thin flat appendages (wings) attached to one side as in CHLOROXYLON, SWIETENIA (fig. 57), CEDRELA, MILLINGTONIA HORTENSIS the Indian Cork tree, TECOMA, and in some species of Pine, that are grown on the higher mountains of India. Or sometimes to both sides, as in DOLICANDRONE (fig. 55), and STEREOSPERNUM. Or the wing may extend all round the seed as in SPATHODEA (fig. 56), where it is very thin scarious and almost transparent.

FIG. 55

SEED OF DOLICANDRONE CRISPA, Seem.

FIG. 56

SEED OF SPATHODEA COMPANULATA, Beauv. The Flame-tree

In order to see the reason for, or the effects of these appendages, drop various winged seeds from the height of a few feet, or throw them up into the air in a light breeze, and mark how far they are carried by the wind. Then cut off the wings and do the same. You will find considerable differences in the distances the seeds are carried in the two cases, especially if the wind is fairly strong.

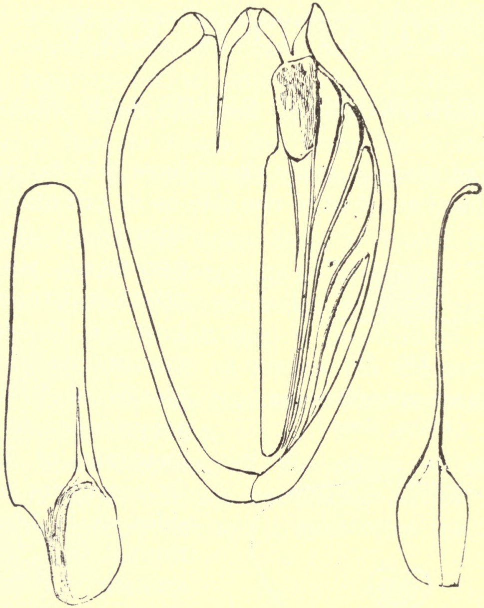

FIG. 57. FRUIT AND SEEDS OF SWIETENIA MAHOGANI, L.

Now, you have only to go into a garden where trees which naturally grow in the open, are planted too close together, or where seedlings have been allowed to spring up under the shade of trees, to see that

they do not, under these conditions, grow well or healthily; the simple reason being that they have not enough light, nor probably enough water and food, because these are taken by the stronger roots of the larger trees. It will, therefore, obviously be on the whole better for the plant that springs up from the seed if it is carried far away from its parent tree. This then is the purpose of wings on seeds.

FIG. 58

DÆMIA EXTENSA. Br.

There are plants, again, whose seeds have a tuft of long fine hairs at one end. Examples of this are common enough, e.g. CALOTROPIS GIGANTEA, which grows on sandy seashores and everywhere inland on sandy and dry hot place in India, CYNANCHUM PAUCIFLORUM, CARALLUMA ADSCANDENS, and many others of the family ASCLEPIADACEÆ (fig. 58). Also NERIUM ODORUM commonly grown in gardens, WRIGHTIA TOMENTOSA (fig. 59), and some others of the family APOCYNACEÆ.

In GOSSYPIUM, the Cotton plant, and other MALVACEÆ hairs grow out from the whole surface of the seed. The effect of these hairy growths is the same as that of the wing in the other cases, the seed is

carried further by the wind before it reaches the ground.

2. The same purpose is effected in the case of many other plants by similar growths on the fruit. Thus in ANOGEISUS LATIFOLIA, the ovary, which is inferior, grows out into two wings. In some species of TERMINALIA, there are five such wings, as also is the case with the fruit of QUISQUALIS INDICA, the common Rangoon-creeper, and COMBRETUM where the five edges of the fruit, corresponding to the five carpels, grow out into thin wings (fig. 60).

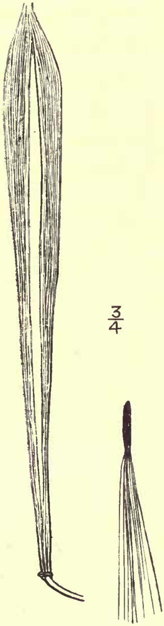

FIG. 59

FRUIT AND SEED OF WRIGHTIA TOMENTOSA

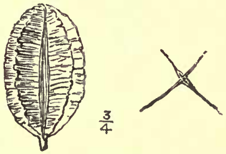

FIG. 60

FRUIT OF COMBRETUM

In HIPTAGE MADOBLATA (fig. 61) belonging to quite a different family, the ovary which is at first three-celled, has in fruit three wings, one to each cell, but only one seed. In some other cases when the fruit has a wing to each cell the cells separate, each with its wing being then a **samara.** And with PTEROCARPUS, PONGAMIA and PTEROLOBIUM, which belong to the family LEGUMINOSEÆ, the fruit has only one seed and is expanded either at one side, or all round, into a wing.

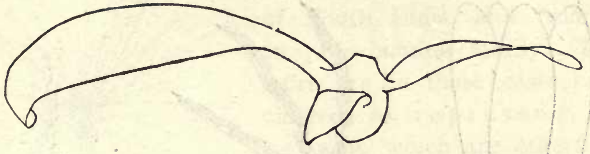

FIG. 61. FRUIT OF HIPTAGE MADOBLATA, Gært.

In others the wings are due to enlargements of some or all of the sepals. Thus in GYROCARPUS JACQUINI (fig. 62) two of the sepals become wings. In HOPEA PARVIFLORA and DIPTEROCARPUS TURBINATA, trees belonging to quite a different family, we can see at once that the wings are enlarged sepals, which though the ovary is in the flower superior, grow out round and above it in the fruit. And in SHOREA ROBUSTA (the Sal-tree) all five sepals become enlarged as wings (fig. 63).

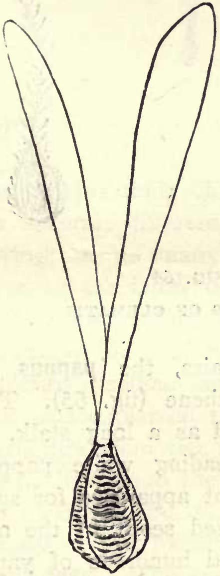

FIG. 62
FRUIT OF GYROCARPUS JACQUINI, Roxb.

Then again, there are fruits with tufts of hairs or hairy appendages answering the same purpose. In CLEMATIS and NARAVELIA, the style of each carpel elongates enormously in fruit, and is also hairy, the hairs being large and pointing forwards like the barbs of a

FIG. 63

FRUIT OF SHOREA ROBUSTA, Gærtw.

FIG. 64

ACHENES OF CLEMATIS

feather (fig. 64). In many of the COMPOSITÆ, e.g. SENECIO, ERIGERON, etc., a circle of hairs, the **pappus,** is formed round the top of the achene (fig. 65). The latter is also sometimes produced as a long stalk, at the top of which are the spreading white pappus hairs. This forms a very efficient apparatus for supporting the fruit (with its enclosed seed) in the air, so that it may be carried several hundreds of yards on a dry sunny day. A good instance is the common Dandelion which occurs as a weed in our hill stations. A pappus is also formed on the fruits of

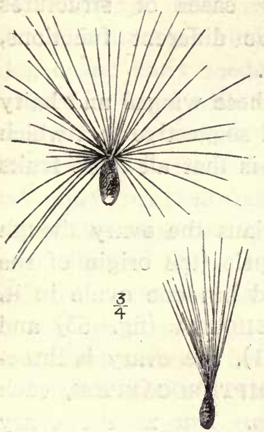

FIG. 65
ACHENE AND PAPPUS

VALERIANA, the Valerian, which grows on the mountains of South India, and belongs to quite another family. The hairs are in these cases considered to represent the sepals, which are otherwise undeveloped and barely visible in the flower.

3. All these outgrowths, wings and hairs, on the fruit or on the seed, have the same effect, to make the seed buoyant and so enable the wind to carry it some distance away from the parent plant. And we see that structures having for their object the same purpose, may arise in several different ways:—as a single enlargement (wing) or as many small outgrowths (hairs) of the seed or the fruit, or as enlargements of the styles or the sepals. The study of plants shows up many instances of the same kind, and of some we have already become acquainted in chapters v and xv. As was explained there, we may regard any organ or structure from the point of view of its function (that is of its use to the plant), or from the point of view of its origin and its connexion with other organs. The study of the former is its **physiology,** of the latter its **homology.** The function of all these wings and hairs on the fruits and seeds is the same, their homology is different.

Conversely there are many cases of structures which are homologous but have different functions, and differ in physiological value.

4. Before we take leave of these winged and hairy fruits there is an interesting and suggestive fact which we may notice about them. It is that all these fruits enclose but one seed only.

In the COMPOSITÆ and Valerians the ovary though theoretically formed of two carpels (the origin of the bifid style) has but one cell and but one ovule in it. In the DIPTEROCARPEÆ, as SHOREA (fig. 63) and HOPEA, and in HIPTAGE (fig. 61), the ovary is three-celled, and, in the case of the DIPTEROCARPEÆ, each has at first two or more ovules. But as the ovary ripens into the fruit, one only of the cells is developed, and in it one only of the ovules becomes a seed. Even with PONGAMIA, PTEROLOBIUM, and PTEROCARPUS which belong to a family the fruit of practically all the other members of which is a legume containing many seeds, there is but one in the fruit.

The reason for this is connected with the fact that the supporting efficiency of a wing or tuft of hairs, depends on the relation between the resistance it offers to the air and the weight of the whole structure. So that obviously a fruit with one seed only in it will be carried further, because it is lighter, than one with several seeds.

Most of these one-seeded fruits, too, are indehiscent, and since the fruit wall itself (ovary) does not open, but remains protecting the seed, the testa may be very thin and so the material necessary for making it, is saved.

5. Another interesting fact comes to light in connexion with the kinds of plants that have these winged and hairy seeds and fruits.

Most of these with winged fruits and seeds are tall trees—DOLICANDRONE reaches to 30 or 40 feet, MILLINGTONIA to 80 feet, CEDRELA, HOPEA, SHOREA, and other DIPTEROCARPEÆ are all tall forest trees, others, like PTEROLOBIUM, grow tall as climbers. The much lighter hairy fruits and seeds, of the COMPOSITÆ, APOCYNACEÆ and ASCLEPIADACEÆ belong, on the other hand, to small plants, and moreover to plants which thrive best in the open—such as CREPIS, SONCHUS, SENECIO, the Dandelion, Thistle, Valerian, CALOTROPIS and Cotton plant. There are exceptions to this, e.g. WRIGHTIA TINCTORIA with small winged seeds is a small not a large tree, and CRYPTOSTEGIA which has hairy seeds is a tall climber, but for the most part this is the case. On the other hand plants which grow naturally under the shade of other trees, as the wild Balsam, Begonia and Nettle, have plain not winged or hairy seeds. Obviously such appendages would not be of much service in dense woods where the seeds could not in any case be carried far by wind.

SPINY FRUITS AND SEEDS

6. There are other fruits which are provided, not with hairs or wings, but with spines or curved or barbed thorns. These readily catch any soft thing that touches them—e.g. the hairy covering of mammals—and in this way the fruit is carried away from the plant. The achenes, for instance, of BIDENS have two barbed bristles just where in others of the

family (COMPOSITÆ) to whom it belongs, there is a pappus of fine hairs. The grains of some grasses have barbed awns that are most annoying to any one who has to walk through tufts of them. The whole flower head of XANTHIUM STRUMARIUM, a very common Indian weed, attaches itself to animals by hooked spines. Again the fruits of TRIBULUS TERRESTRIS, another common weed have short hard spines which stick in the feet of animals and are thus carried along, as are those of TRAPA, in which the spines serve also to anchor the fruit while it germinates.

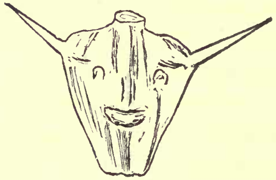

FIG. 66
FRUIT OF TRAPA BISPINOSA Roxb.

It is worthy of note that all these fruits are achenes, or have but few seeds—even when as in XANTHIUM the spiny fruit is really a whole flower head, such as in others of its family, e.g. the Sunflower, contains a multitude of florets, each with its own ovary. The reason for this is perhaps akin to that suggested for the similar phenomenon in the case of fruits carried by wind.

THE COLOURS OF FRUITS AND SEEDS

7. It has been said that it is to attract insects, for the purpose of cross-pollination, that petals are coloured or flowers sweet-scented. Fruits and seeds are also often specially coloured, not so commonly or brilliantly, perhaps, as flowers, but still much more commonly and usefully than most people imagine.

Dry dehiscent fruits, capsules follicles, etc., are usually of a dull brown or yellowish colour, and so are usually the seeds they contain, but fleshy fruits are generally when ripe, highly coloured—red, yellow, purple or black. The mango, cashew fruit, jujube (ZIZYPHUS), pomegranate, apple, grape, are common instances of this. Some of these have also green-fruited varieties, more especially cultivated plants, e.g. green grapes, but among wild plants, fleshy fruits drupes and berries are much more commonly coloured in such a way as to be very conspicuous against the green foliage. In most cases, too, the colour develops as the fruit ripens, only becoming conspicuous, whether red, yellow, purple or black, when quite ripe. This is just the opposite to what happens with dry fruits and their seeds. While they are on the plant capsules are, like unripe fleshy fruits, green and hidden away among the leaves, but by the time the seeds have ripened, they are brown or black and though conspicuous perhaps on the tree, their contents, the seeds, being now of a dull brown or black colour, are almost invisible against the brown soil on to which they fall.

For this difference there must be a reason, and we find the reason lies, as in the case of flowers, on the inter-dependence of animals and plants. Seeds being, as we saw in chapter v, packed full of highly concentrated foodstuffs, are much sought after by animals, and if it were not for the inconspicuous colouration of the unripe pods on the plant, and of the ripe seeds after they have fallen to the ground, would soon be eaten by birds, squirrels, rats and larger creatures. It is to increase, therefore, the

chances of successful germination of its seeds, that a plant colours its unripe pods green, and its ripe seeds brown or black.

8. But fleshy fruits are freely exposed, and we must suppose that it is not only not harmful, but actually an advantage to such a plant that its fruits should be eaten. The reason for this lies in the second point about plant propagation—the advantage to the species that its seeds should be scattered widely, which is the reason as we have seen for winged and spiny fruits and seeds. When an animal eats a fleshy fruit, it is for the pulp that it does so, the seeds and stones are usually rejected or passed out in its dung. And here we see the reason for the hard stony endocarp that surrounds the seed of a drupe—it protects the seed from injury. In all drupes the seed is protected in that way. In berries the seed has no outside protection, but it makes up for this by its superior numbers (for if only one of the many seeds in a Grape or any other berry were to survive and germinate it would be more than enough to preserve the species in undiminished numbers). Moreover in many cases the seeds are hard, as with the Date and Coffee, or have very hard testas, those for instance of the Guava are as hard as the stones of most drupes. This is not always the case, but it is so very often, and the hardness prevents the seed being crushed by the animal's teeth, or damaged by the digestive juices of its stomach and intestines. It has, indeed, been found that some seeds germinate better when their seed-coats have been partially digested and softened by the digestive juices of an animal. When the seed is

not itself hard, it is often protected in some other way, e.g. the seeds of the orange are very slippery and bitter. We must not forget that a seed which is dropped by an animal with its dung, has the further advantage of a richly manured soil to germinate in, and that much depends on the first stages of a plant's growth.

9. But there are some seeds which though borne in dry capsule, are so brilliantly coloured as to be conspicuous from a considerable distance. For instance, the small red and black or white seed of ABRUS PRECATORIUS which is used by jewellers and goldsmiths for weighing, the red seeds of ADENANTHERA and the scarlet seeds of BIXA (fig. 53).

The plant in this case seems to be trading on the inquisitiveness and curiosity of birds. For it should be noticed that, in the first two of these plants, the seeds are very hard and very smooth, so hard and smooth that it would require a powerful beak to break them. A bird which picks such a seed, but finding it too hard to crack, drops it while flying, or swallows it whole and ejects it in its dung, thereby carries it some distance from the tree.

But the plant is not content with merely colouring the seeds. Look at an ADENANTHERA tree when its seeds are ripe. The brown pod opens, and then the sides twist back so as to expose the seeds, which do not fall at once as happens in most pods, but remain attached by their funicles, and are all the more conspicuous because of the silvery white surface against which they rest. Here we find that not only the seed coat, but the inside of the pod also is coloured to

make the seeds conspicuous. Again the seeds of the common Wattle, ACACIA MELANOXYLON, are jet black and stand out very clearly against the white inside of the pod, and are made still more conspicuous by the long red funicles. They too, like that of ADENANTHERA, hang long in the pod.

There are many instances of this to be found among Indian plants, and in the same way we find often coloured fruits rendered more conspicuous by the arrangement of the back-ground of leaves.

10. In many cases it is, perhaps, not from curiosity but because mistaking it for some small insect, that a bird picks up a highly coloured seed. The castor-oil seed has a decided resemblance to a ground beetle; the regularity of the marking of the rounder surface, suggests a beetle's wing-cases, the caruncle its head. It may be that birds occasionally mistake them for beetles, but finding the seed-coat too hard to crush, drop them again. The seed here does not stay in its pod, but falls as soon as ripe to the ground. The 'seeds' (achenes) of the common garden Marigold, CALENDULA OFFICINALIS, are so like fat green caterpillars as to have deceived people when looking at them even in the palm of the hand. These achenes again do not remain long on the plant, but soon fall to the ground.

It was remarked above that small plants with hairy seeds and fruits that are adapted to distribution by wind, are commoner in open spaces than in woods, and if we think of the plants which have fleshy fruits or conspicuous seeds, we shall find that they are in early all cases trees or large shrubs, or, are herbs and

climbing shrubs which like the wild Strawberry and Passion-flower naturally grow in the shade of trees or on the outskirts of woods, i.e. in just those places where birds and other animals are commonest.

All these differences in fruits and seeds, show how beautifully plants are adapted in this respect as in others, to the conditions of their life.

PART II

AN INTRODUCTION TO

SYSTEMATIC BOTANY

OR

PLANTS IN THEIR RELATIONSHIPS WITH EACH OTHER

In the following pages are described in technical terms, a few of the commoner species of the more important families. It is intended that each description be read with the plant, or specimen referred to, before the reader, and it cannot be too strongly kept in mind that unless close attention is at the same time paid to the actual specimen, the reading of these, or any, descriptions is worthless. Each genus is taken by itself, and the characters they have in common, and because of which they are united in the family, are pointed out.

* Denotes those found only in cooler climates, e.g. in South India, on the hills.

I

DICOTYLEDONS

* RANUNCULACEÆ

Examples:—

* ANEMONE RIVULARIS, Ham., the common white anemone of our hill stations.

The plant has a short thick root-stock (or vertical rhizone) with an erect branching stem above ground.

Leaves radical and divided into three wedge-shaped parts which may be again three lobed. Flowers on long branches, with a pair of three-fid bracts a few inches below each. Sepals from five to eight in number, $\frac{1}{2}$ to 1 inch long, white. Petals absent (see ch. xviii, sect. 2). Stamens very numerous. Ovary in the centre of the raised thalamus, of several free carpels each in fruit containing one seed, so that the fruit consists of a number of achenes. Both stamens and carpels are arranged spirally on the thalamus, not in two circles.

Another species of this genus is often grown in gardens under the name 'Japanese Anemone' (A. JAPONICA).

* THALICTRUM JAVANICUM, Bl., the Meadow Rue of South Indian hills, is distinguished from Anemone by not having the three bracts on the stalk of each flower. It is interesting because not only has it no petals, but the four sepals fall off when they open out, so that

the flower appears to be quite naked, a fluffy ball of delicate white stamens. The leaves are ternately divided into a number of leaflets, which have rather the appearance of those of the maiden-hair fern. The stamens are numerous, the ovary consists of many free carpels, each with one seed and becoming in fruit an achene.

* RANUNCULUS WALLICHIANUS, W. & A., and R. RENIFORMIS, Wall., are two Buttercups, common on the hills. They have thick rootstocks; radical and alternate leaves, the former clasping the stem at the base, with blades deeply cut into wedge-shaped segments and these again cut, the latter undivided and coarsely toothed. The flowers are on long stalks. Sepals generally five in number. Petals five, shining, bright yellow, with at the base of each, a small pocket covered by a flap in which honey is formed. Stamens very numerous, arranged in a spiral, not in one circle. Carpels also numerous, arranged in a spiral at the top of the dome-shaped thalamus, and in fruit achenes.

CHARACTERS OF THE RANUNCULACEÆ

These three genera, it will be at once seen, have in common: the perennial rootstock and alternate and more or less divided leaves; the flowers single or on long stalks (not in masses); the sepals free; the petals free (or it may be absent); the stamens and carpels indefinite in number (generally very numerous) spirally arranged and free; and the end of the pedicel (the thalamus) on which the parts are placed, dome-shaped (not flat nor hollow). These are the characters of the RANUNCULACEÆ. It is not a large family, and

it belongs chiefly to the cooler parts of the world. But it is in many ways important, and many of the genera are very well known as garden plants.

Other genera.

* CLEMATIS WIGHTIANA, Wall., is found wild on the higher hills and C. GOURIANA, Roxb., lower down. They are climbers with opposite pinnate leaves, and support themselves by their petioles. The flowers have no petals, but the sepals are white and showy. The fruit is commonly known as 'Old man's beard' because of the long feathery tails, formed by the elongation of the styles of the carpels (fig. 61). By these the achenes are easily carried by the wind.

* AQUILEGIA (Columbine) * DELPHINIUM (Larkspur) and ACONITUM (Monk's Hood) are often grown in gardens. Their flowers look very unlike those of the Buttercup, especially the latter two which are irregular in shape, but the petals are separate, the stamens numerous, and the carpels of the ovary are free. They differ from RANUNCULUS and CLEMATIS in that the carpels have several seeds when ripe, and in other minor points.

We have here a good instance of the degree of importance, with respect to the classification of plants, which is attached to different characteristics. Mere shape—whether of leaves or flowers—counts for very little because, as stated on p. 235, it may be modified for some special class of insect, as it certainly is in the case of these genera, for bees. Of much greater importance are the numbers of each kind of organ, especially of the stamens and carpels, and whether they are united or not.

ANONACEÆ

Examples:—

ARTABOTRYS ODORATISSIMUS, R. Br., a smooth scandent shrub with long branches (fig. 67). The leaves

FIG. 67. ARTABOTRYS ODORATISSIMUS, R. Br.

are alternate spreading in two ranks to right and left (that is, bifarious, not in a spiral), short-petioled, lanceolate, from three to six inches long, entire, coriaceous and glabrous and often rather waved. The

leaf-scars are V shaped. The flowers are borne at the end of the branches which are curved over as hooks, they have three broadly ovate sepals, and six long petals, the three outer ones alternating with the sepals, and three inner alternating again with the outer (and so opposite to the sepals). The base of each outer petal is curved, expanded and concave, while above the petal is extended as an oblong blade. The stamens are numerous, closely packed and each has a very short filament. The anther is wedge-shaped (cuneate), broader above and covered by the extension of the connective. The carpels are many, free, with short styles protruding in the centre of the mass of stamens. In fruit each carpel becomes fleshy and contains one seed, which if cut open shows peculiar lines extending on from the seed-coat into the endosperm, i.e. is **ruminate** (p. 254).

POLYALTHIA LONGIFOLIA, Benth., a tall tree whose foliage is that usually employed in South India for decorative purposes on special occasions. Branches round and thin, with numerous small lenticels. Leaves alternate in two ranks, to right and left, and all facing upwards (bifarious). Petiole ¼ inch blade lanceolate, entire, waved at the edges, membranous, with numerous minute glands easily seen as clear dots, when a young leaf is examined against the light through a magnifying glass. It is the oil in these glands which gives to the leaves their peculiar smell when crushed. Flowers yellowish green in colour. Sepals three. Petals six inner and three outer, narrow. Stamens very numerous, tightly packed in spiral lines on the very convex thalamus. Filament very short, connective

expanded above as a cap. Carpels many, when ripe one-seeded.

ANONA SQUAMOSA, L., the Custard-apple. A small tree. Leaves alternate, exstipulate, bifarious, simple, oblong, entire, membranous, glaucous on the lower side and pubescent when young.

Flowers solitary. Sepals three. Petals three, narrow, oblong and very thick, with concave bases. Stamens very numerous each with a thick cap—an extension of the connective. Carpels also numerous, in the centre of the flower, each with its own very short style. If the flower be cut down perpendicularly, it will be seen that the stamens and carpels are on a very much raised, conical, thalamus. The fruit is an aggregate of fleshy carpels, densely packed together, each with one seed. Endosperm ruminate.

The fruit of A. RETICULATA, L., is the Bullock's-heart, so called from its shape and pink colour. The surface is smooth and marked by a faint network (reticulation) of lines between the many carpels. That of A. MURICATA, L., is the Sour-sop. In this the separate carpels protrude a little, as so many lumps making the whole fruit knobby (muricate).

CHARACTERS OF THE ANONACEÆ

This family of plants consists of trees and shrubs (some climbing) and is chiefly found in the Tropics of Asia and Africa. Many of them have sweetly-scented flowers or luscious fruits, and are cultivated for that reason, e.g. CANANGA, ARTABOTRYS and ANONA the Custard-apple. The leaves are always alternate generally in two rows and bifarious, petioled, simple

and entire, without stipules, and have often an aromatic smell. The flower is regular and has a high conical thalamus. The sepals are three; the petals six in two series, or only three; the stamens many, closely packed in spirals on the conical thalamus, with very short filaments, and the connectives produced as a sort of crest or head on the top of the anthers. The ovary consists nearly always of numerous separate carpels spirally arranged and each with its own stigma. The seeds are large with hard endosperm into which the seed-coat projects in plates (ruminate), while the embryo is very small.

The family is easily distinguished by the flowers having sepals and petals in three's, by the numerous spirally placed stamens, by the anthers having expanded connectives, and by the numerous free carpels and large seeds with ruminate endosperm.

NYMPHÆACEÆ

Examples:—

NELUMBIUM SPECIOSUM, Willd., the Sacred-lotus, a well-known plant which can be found in many temple tanks. The plant is fixed by the roots to the mud at the bottom of the water, and has a number of leaves with long stalks and round peltate blades, the surface of which is such that drops of water coming on them do not stick, but can be rolled about and easily fall off without wetting the surface.

The flowers are borne singly on tall leafless stalks (scapes). Sepals four or five. Petals numerous almost round, without any stalk or claw. Stamens also

numerous, the anthers with an appendage and opening in two long slits. In the centre of the flower is an inverted cone-shaped organ, a peculiar shaped thalamus, in the top of which are inserted several carpels each containing one seed. The sepals, petals and stamens soon fall off, and leave this structure with its enclosed carpels to harden.

NYMPHÆA LOTUS, L., the common Water-lily of Indian tanks and streams. This plant grows in water, rooted to the mud at the bottom. The leaves have long stalks, which, if cut open, can be seen to be very spongy, and to contain numerous open channels running along the length. Blades sagittate, or deeply cleft at the base, sharply sinuate or toothed. The upper surface very smooth and shiny so that water easily rolls off it, the lower rough with large veins, and of a purplish colour. Flowers on long scapes, floating usually on the water. Sepals four, oblong. Petals many. Stamens also many, the outer ones broad especially at the base, and resembling the petals. Ovary slightly sunk in the disc, of many cells, with seed attached all over their inner surfaces; stigma sessile on the ovary, in the form of a number of velvety rays. Fruit a berry ripening under water, seed very small, each enclosed in a little sac (aril) and immensed in the pulp of the berry. Embryo small, in a small endosperm itself surrounded, except at the apex, by perisperm.

Another common example of this family is N. STELLATA, Willd., which has white, blue or pink flowers and differs from N. LOTUS in the anthers having appendages, the rays of the stigma ending in short horns, and the leaves being more or less circular.

CHARACTERS OF THE NYMPHÆACEÆ

The members of this family are characteristically water-plants. The stalk of the leaf and of the flower is very spongy in texture, containing long tubular air passages, which make them float in the water, and also no doubt allow air to pass more freely from the blades to the roots and vice-versa. The purple colour of the underside of the leaf seems to have some protective function, though we do not exactly know what, while the smoothness of the upper surface undoubtedly serves to keep them from becoming wetted. The family is remarkable for the large flowers borne singly, and for the indefinite number of the petals and stamens, which grade imperceptibly into each other. The carpels are also numerous and indefinite in number and, except in NELUMBIUM where there is only one in each carpel, the ovules are attached all over the inner side of each cell, not at the inner angle, as is usually the case. This arrangement, or non-arrangement, of the ovules is very remarkable, occurring in practically no other family (p. 227).

CAPPARIDEÆ

Examples:—

GYNANDROPSIS SPECIOSISSIMA, a herb very commonly grown in gardens. Leaves alternate petioled, palmately compound, with seven radiating leaflets, and no stipules. Leaflets two to three inches long, oblanceolate, obscurely acuminate, herbaceous.

Flowers in terminal racemes, the uppermost leaves simple and bract-like. Sepals four. Petals four pinkish

purple in colour, weak and spreading, clawed, that is, with a distinct blade and stalk. Stamens six raised upon a central axis, filaments pink and very conspicuous. Ovary also stalked, on a continuation of the staminal stalk, one celled with very short style; stigma nearly sessile, bilobed; ovules many on two parietal placentas. Fruit a narrow capsule, with many kidney-shaped black seeds. Embryo, in the seed, bent.

Another species of the same genus which grows wild in most places, is G. PENTAPHYLLA, D.C. The leaflets are five not seven, and the racemes—the pedicels, etc.—are slightly sticky.

CLEOME is another genus, very like GYNANDROPSIS, but the stamens are sessile in the flower, not raised together on a stalk above the sepals and petals.

CLEOME VISCOSA, L., is very common by roadsides. The whole plant is very sticky, being covered with glandular hairs. The leaves are digitate with three—five leaflets, the flowers about ½ inch long and yellow in colour.

C. ASPERA, Koen., grows in sandy places. It is covered over with minute prickles (whence the name aspera meaning rough). The leaves have three leaflets, each ¼ to ½ inch long. The flowers are ¼ inch long, yellow.

CAPPARIS SEPIARIA, L., a straggling shrub, with thin wiry branches, found growing everywhere in dry hot places all over India. The branches are covered with a greyish pubescence, and armed with curved thorns in pairs at the base of each petiole (and therefore to be considered as modified stipules, cf. ZIZYPHUS in

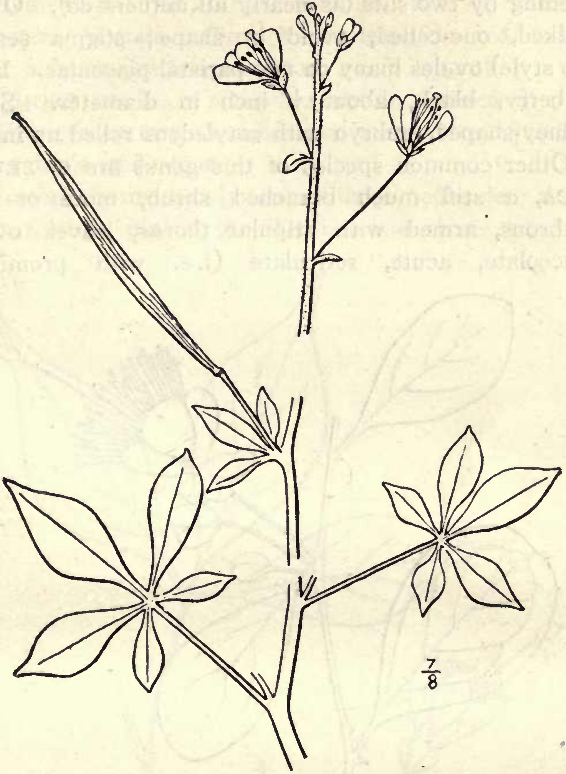

FIG. 68. CLEOME VISCOSA, L.

the RHAMNEÆ). Leaves alternate nearly sessile, ovate, elliptic or lanceolate, entire, covered with short thin hairs ('down') on the lower surface, venation pinnate.

Flowers in umbels about ½ inch diameter. Sepals four green. Petals four white 'clawed' (i.e. with distinct blade and stalk). Stamens many, anthers

opening by two slits (as nearly all anthers do). Ovary stalked, one-celled, ovoid in shape; stigma sessile, (no style) ovules many on two parietal placentas. Fruit a berry, black, about $\frac{1}{2}$ inch in diameter. Seeds kidney-shaped, embryo with cotyledons rolled up inside.

Other common species of this genus are C. ZEYLANICA, a stiff much branched shrub, more or less glabrous, armed with stipular thorns, leaves ovate-lanceolate, acute, reticulate (i. e. with prominent

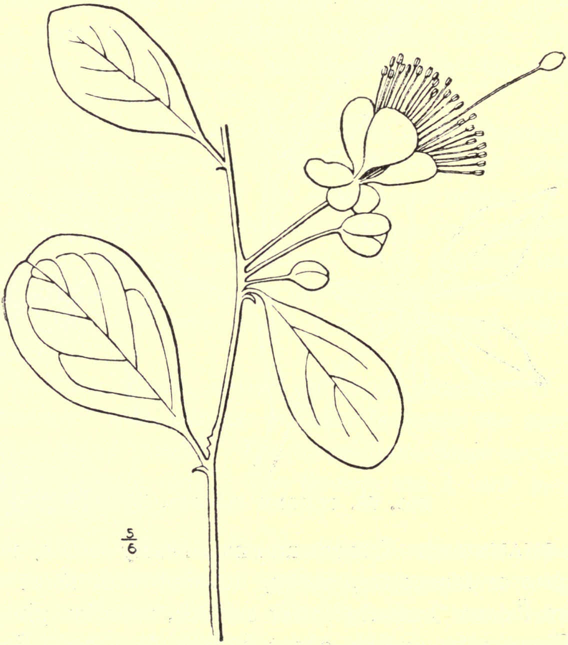

FIG. 69

CAPPARIS HORRIDA, L.

net-like veins) beneath. Flowers two inches in diameter. Petals yellowish changing to red-brown. Fruit a berry, two inches long, ovoid smooth.

C. HORRIDA, L., a straggling shrub, covered all over the younger parts with red-brown tomentum. Stipular thorns large and stout.

Flowers borne singly on axillary peduncles, three or four being placed serially (i.e. one above another)

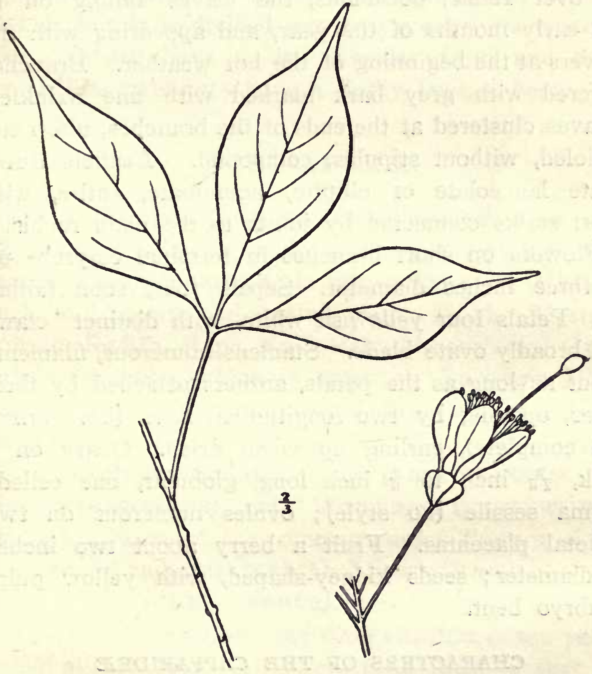

FIG. 70

CRATÆVA RELIGIOSA, Forst

in each axil, the topmost opening first. Petals white or pinkish, filaments long, white at first, and soon turning purple. Ovary globular on a stalk, a little longer than the numerous stamens; no style. Fruit a berry an inch or more in diameter, red-brown in colour, smooth, seeds many.

CRATÆVA RELIGIOSA, Forst., a tree, native of the western side of the peninsula, but cultivated in gardens all over India; deciduous, the leaves falling off in the early months of the year, and appearing with the flowers at the beginning of the hot weather. Branches covered with grey bark marked with fine wrinkles. Leaves clustered at the ends of the branches, alternate, petioled, without stipules, compound. Leaflets three, ovate lanceolate or elliptic, acuminate, entire, with short stalks connected by joints to the main rachis.

Flowers on short branches in terminal corymbs up to three inches diameter. Sepals four, soon falling off. Petals four yellowish white, with distinct 'claw' and broadly ovate blade. Stamens numerous, filaments about as long as the petals, anthers attached by their bases, opening by two longitudinal lines (i.e. normal and complete), curling up when dried. Ovary on a stalk, $\frac{1}{16}$ inch to $\frac{1}{6}$ inch long, globular, one celled; stigma sessile (no style); ovules numerous on two parietal placentas. Fruit a berry about two inches in diameter; seeds kidney-shaped, with yellow pulp. Embryo bent.

CHARACTERS OF THE CAPPARIDEÆ

Comparing these examples, we see that this family comprises herbs, shrubs and trees, having alternate,

simple or digitately compound leaves. Stipules may be present or developed as thorns or absent altogether.

The flowers are alike in having four sepals, four petals, numerous stamens and a one-celled ovary, which except in some species of CLEOME is raised up on a long stalk. The seeds are arranged on two parietal placentas, showing that the ovary is to be considered as made up of two carpels. There is no style, the stigmas being sessile, or practically so.

This family is divided into two groups, those which like CLEOME have a dry capsular fruit, and those which like CAPPARIS have a fleshy fruit, a berry.

* CRUCIFERÆ

AKIN to the CAPPARIDEÆ is the CRUCIFERÆ, a large and important family in the cooler parts of the world (where the CAPPARIDEÆ do not occur). To it belong such well-known and useful plants as the Mustard, Turnip, Radish, Rape, Kohl Rabi, Broccoli and Cauliflower (the part which is eaten at European tables is the enormously exaggerated branched and fleshy inflorescence, before the flowers are fully formed) all of which are varieties of the genus BRASSICA; the Radish (RAPHANUS), and * Watercress (NASTURTIUM), as well as some of the common garden flowers of hill stations, * Candytuft (IBERIS), * Stock (MATHIOLA) and * Wallflower (CHEIRANTHUS).

The family resembles the CAPPARIDEÆ in the petals being always four, but differs from them in that the stamens are six only, the ovary has no stalk, and there is a partition joining the two placentas.

Examine carefully the flower of a Stock, Wallflower or Mustard (or any of those) mentioned above. The flowers are always in racemes, with no bracts or bracteoles. The sepals always four, the petals four, with long claw and horizontally spreading limb. Of the six stamens notice that the short ones stand opposite two sepals, while the four long ones stand in pairs opposite the other sepals. Obviously, therefore, each pair of long stamens is derived by splitting from one, which would stand naturally opposite that sepal (compare chapter xx, p. 220 where similar evidence is adduced in support of the idea that a bunch of stamens has been derived from one by a process of splitting).

Note too that the two sepals which correspond to the short stamens bulge out slightly at the base. This is to make room for the secretion of honey at the bottom. The flower of the Candytuft is irregular, two petals being larger than the other two, but almost all other CRUCIFERÆ have perfectly regular four-merous flowers.

MALVACEÆ

Examples:—

SIDA HUMILIS. A herb with slender procumbent branches found everywhere in the hotter parts of India. The whole plant is more or less hairy, with both simple and short branched hairs, especially on the younger parts. Leaves alternate, stipulate, petioled, broadly ovate, acute, serrate.

Flowers on axillary branches, with bracteoles where they branch again, or perhaps only a joint at about

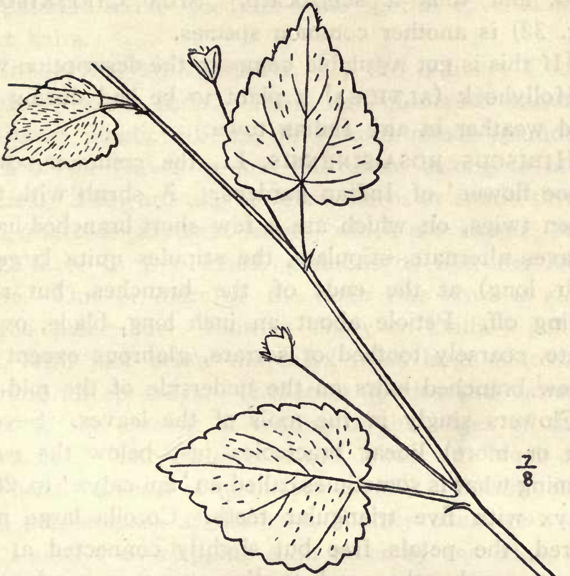

FIG. 71

SIDA HUMILIS, Willd.

the middle. Sepals in the form of a cup with five triangular teeth. Corolla about ½ inch in diameter of five petals which though slightly connected at the base, to each other and to the stamens, are considered as really 'free', and in bud overlap each other, and are twisted. Stamens in the form of a tube surrounding the style, with numerous anther-bearing connectives. Anthers kidney-shaped opening by one slit. Ovary five-celled with as many styles, and one ovule in each cell (or carpel). Fruit of the five separated carpels, each with two short awns (spines), and one

seed, and thus a schizocarp. SIDA CARPINIFOLIA (fig. 32) is another common species.

[If this is not available compare the description with a Hollyhock (ALTHÆA) a plant to be had during the cold weather in any Indian town.]

HIBISCUS ROSA-SINENSIS, L., the common scarlet 'shoe flower' of Indian gardens. A shrub with thin green twigs, on which are a few short branched hairs. Leaves alternate, stipulate, the stipules quite large ($\frac{1}{3}$ inch long) at the ends of the branches, but soon falling off. Petiole about an inch long, blade, ovate, acute, coarsely toothed or serrate, glabrous except for a few branched hairs on the underside of the mid-rib.

Flowers singly in the axils of the leaves. Several (six or more) linear bracteoles just below the calyx forming what is sometimes called an 'epi-calyx' (p. 207). Calyx with five triangular teeth. Corolla large pink or red, the petals free but slightly connected at the base to each other and to the stamens, overlapping each other and twisted in the bud. Stamens in the form of a staminal tube surrounding the style, with numerous connectives bearing kidney-shaped anthers which open by one slit. Style single but branching above into five arms each with a large round velvety stigma. Ovary five-celled. The usual garden varieties do not set seed, the pollen being apparently quite infertile; but the original species, H. ROSA-SINENSIS is sometimes grown and does ripen seeds, and there are many other wild species of the genus which do. The fruit is dry and dehiscent, the outer wall breaking between the partitions—a loculicidal capsule. Ovules attached to the inner angles of the cells—

placentation axile—seeds in some species covered with short hairs.

Gossypium herbaceum, L., the ordinary Cotton plant of South India. There are numerous varieties of Cotton plants, differing in various minor characteristics of the leaves or lint, and some belong to other species. They are all, however, herbs or small shrubs with alternate stipulate leaves, which are simple, petioled, three to five lobed, glabrous or not, the lobes entire. One or more of the main ribs have a gland on the under side. Flowers singly on axillary peduncles, with just below the calyx three large bracteoles forming an epi-calyx. (Different species and varieties differ in the amount of cutting of the edges of these bracteoles.) Calyx almost entire, a cup with black dots and hardly a trace of teeth (see p. 207). Petals yellow with purple mark at the base, slightly connected with the stamens, overlapping each other by one edge, and twisted in bud. Stamens forming a staminal tube round the style, with numerous connectives each with a curved or kidney-shaped, anther, which opens by one slit. Style single swollen at the end, but not divided. Ovary three (sometimes four) celled. Fruit opening by the outer wall splitting down between the partitions and rolling back so that the seeds escape, and therefore a loculicidal capsule. Seeds attached originally to the inner angles of the cells, covered with long white hairs (cotton).

Eriodendron anfractuosum, D.C. A tree with a straight rather prickly bent and whorls of branches sticking out stifly at right angles; conspicuous enough in the early months of the year when the leaves have fallen and the branches are bare.

Leaves alternate, digitately compound, leaflets lanceolate, cuspidate, entire or serrulate towards the point, glaucous beneath, and with small stipules.

Flowers appearing before the leaves, in tufts at the ends of the branches, each singly on its peduncle large, white or rose coloured. Calyx cup-shaped, cleft into five teeth. Petals five, slightly connected at the base, overlapping each other. Stamens many in five bundles set opposite the petals, each with two or three long curved anthers, which open each by one curved line. Ovary five celled, style single, stigma five lobed. Fruit dry (a capsule) containing many seeds but opening only slowly. Seeds black.

CHARACTERS OF THE MALVACEÆ

Comparing these examples of the MALVACEÆ, we see that the family contains herbs, shrubs and trees, with alternate stipulate leaves which may be simple or palmately compound. Some at any rate have branched, (stellate) hairs scattered over the younger parts.

The flowers are large and borne singly, not in massed inflorescences, and may have an epi-calyx of bracteoles just below or on the calyx itself. Sepals five free or as a calyx cup. Petals five overlapping each other and twisted. Stamens many united together into one staminal tube or into five bundles, and connected at the base with the petals. Anthers opening by one line only, and more or less kidney-shaped. Ovary of several cells with axile placentas, styles as many, or single, branched or not. Fruit a schizocarp, or capsule, seeds in the latter case numerous and sometimes covered with long hairs (cotton) with a curved embryo inside.

Other fairly common or well-known members of this family are ALTHÆA ROSEA (the Holly-hock) a well-known garden plant, of a typically malvaceous character. The flowers are large (in garden varieties often double, that is, with numerous petals). They have an epi-calyx of several bracteoles, and the fruit is a schizocarp, splitting into a large number of one-seeded segments.

ABUTILON INDICUM an undershrub with cordate almost entire leaves covered with soft 'down'. The

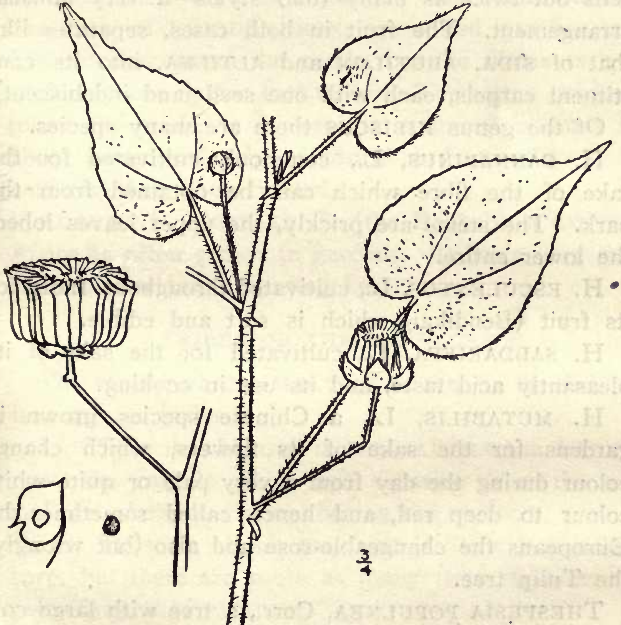

FIG. 72. ABUTILON INDICUM, G. Don.

flowers are very like those of SIDA, but are larger and open in the evening. The fruit is an inch or more broad and flat, and divides into a number of carpels, each with one or more seeds. These carpels open to let the seeds out, and so are different from the carpels of SIDA, the fruit of which is a true schizocarp.

PAVONIA ZEYLANICA, Cav. and PAVONIA ODORATA, Willd. are two herbs found growing wild in fields in South India and Ceylon. They have grandular hairs which make them very sticky. The ovary has five cells but twice as many (ten) styles—a very unusual arrangement. The fruit in both cases, separates like that of SIDA, ABUTILON and ALTHÆA, into its constituent carpels, each with one seed (and indehiscent).

Of the genus HIBISCUS there are many species.

H. CANNABINUS, L., commonly cultivated for the sake of the fibre which can be obtained from the bark. The stems are prickly, the upper leaves lobed, the lower entire.

H. ESCULENTUS, L., cultivated throughout India for its fruit (Bendikai) which is soft and edible.

H. SABDARIFFA, L., cultivated for the sake of its pleasantly acid taste, and its use in cooking.

H. MUTABILIS, L., a Chinese species grown in gardens for the sake of its flowers, which change colour during the day from a very pale or quite white colour to deep red, and hence called sometimes by Europeans the changeable-rose and also (but wrongly) the Tulip tree.

THESPESIA POPULNEA, Corr., a tree with large cordate leaves and yellow flowers, grows naturally along the sea coasts of Tropical India and Ceylon. The fruit

is like that of HIBISCUS or GOSSYPIUM, that is, it is a capsule, but opens irregularly. It is very light and floats easily in the water. The flower is like that of GOSSYPIUM, with a single undivided style, but the three bracteoles (epi-calyx) are small and fall off before the flower opens, leaving only three scars.

BOMBAX MALABARICUM, D.C., the well-known silk-cotton tree, is like ERIODENDRON, deciduous, its leaves falling off early in the year and the new ones not appearing till after the gorgeous deep pink or scarlet flowers. The calyx is a leathery cup. The stamens like those of ERIODENDRON, are united into five bundles set opposite to the petals, but the filaments have each only one anther (not three). The cotton produced round the seeds, is useless for spinning because the fibres being perfectly cylindrical and smooth will not hold together when twisted.

ADANSONIA DIGITATA, L. (the Baobab), a native of Africa is often grown in gardens. It has a very thick stem, and widely spreading branches.

TRIBES OF THE MALVACEÆ

The family of the MALVACEÆ can be divided into four groups (tribes).

I. Those in which, as in SIDA, ALTHÆA and ABUTILON, the carpels when ripe separate from the axis, and are of the same number as the styles.

II. Those in which the fruit is likewise a schizocarp, but there are twice as many (ten) styles as carpels (five), e.g. PAVONIA.

III. Those which like HIBISCUS and GOSSYPIUM have loculicidal capsules.

IV. Those in which, as in ERIODENDRON and BOMBAX, the sepals are thick or leathery, and the stamens are not in one tube as in the other groups, but in five distinct bundles. They are all trees, and the fruit is usually a capsule which opens irregularly.

STERCULIACEÆ

Example:—

STERCULIA FŒTIDA, L., a tall tree with bark that comes off in patches, and whorls of thick branches, their ends and buds covered with thick brown tomentum of matted hairs. Leaves alternate and digitately compound.

Flowers in panicles of two-flowered cymes, in whorls at the ends of the branches, just beneath the new leaves of the year. Pedicels jointed, flowers of five thick green sepals, concave and pubescent on the inner side, valvate. No petals. Stamens monodelphous in a staminal column with an expanded cup-shaped top on which are sessile twelve two-celled anthers. Ovary surrounded by the anthers, sessile on the staminal column, five lobed, with one stout central style. Fruit a follicle developing from one cell (carpel) of the ovary containing ten or more large black seeds, without endosperm.

Other species common enough are S. URENS in which the bark also flakes off in patches, with palmately lobed (not compound) leaves, and five follicles to each flower (fig. 52), and S. BALANGHAS, L. with simple one-nerved leaves.

CHARACTERS OF THE STERCULIACEÆ

The STERCULIACEÆ are a family of plants, confined to the tropics. They comprise herbs, shrubs and trees. The ends of the young twigs, and the surface of the newly-opened leaves are often covered with a dense brown tomentum of branched hairs, and this though not confined to the STERCULIACEÆ, is very characteristic of the family.

The leaves are alternate, stipulate, simple or digitately compound. The flowers, generally small and inconspicuous because of the absence of petals, are arranged in a cymose inflorescence, regular and five-merous. Sepals five, petals five or none. Stamens five to ten or fifteen, monodelphous as a tube round the stalk of the ovary, anthers normal (two-celled) in a ring or on the edge of a cup, sometimes with staminodes, under the ovary. Ovary five-celled—generally separating in fruit into its five constituent carpels, but sometimes becoming a berry or woody capsule.

By its description the family may appear to resemble the MALVACEÆ, but there is never an epi-calyx (bracteoles, as often in the latter, and the anthers are two-celled not one-celled. The flowers too are usually small and many together, not at all like the large showy, generally singly borne flowers of the MALVACEÆ, so that the two families are not really like each other. Economically the most important plant of the family is THEOBROMA CACAO, whose orange red fruits, looking like inflated cucumbers, contain the seeds from which cocoa and chocolate are made.

GUAZUMA TOMENTOSA, Ku., is a small tree common, in Indian gardens and by road sides. The leaves are simple, ovate-cordate, minutely crenate-serrate, and oblique at the base. The young parts are covered with a yellowish pubescence. The flowers are small, but have golden yellow petals, each with a concave base and divided beyond into two narrow strap-like lobes. The fruit is a capsule covered with black sharply angled knobs.

HERITIERA LITTORALIS, Dry. grows by the seashore. Its leaves are very thick, the flowers about $\frac{1}{8}$ inch long, companulate, and the carpels in fruit are extended on one side as a wing.

PTEROSPERMUM has winged seeds hence its name.

TILIACEÆ

Examples:—

CORCHORUS CAPSULARIS, L., the Jute plant. An annual herb grown for the fibre which is obtained from the bark.

Leaves alternate, stipulate, petioled, oblong, acuminate, coarsely toothed with two narrow projections at the base, nearly glabrous. Venation pinnate, but in addition to the mid-rib two other veins radiate from the base of the blade and themselves branch towards the margins. Stipules lanceolate acute.

Flowers in short cymes, axillary to or opposite the leaves, small, yellow. Sepals five. Petals five. Stamens many, the thalamus from which they spring slightly raised. Ovary two or more celled, with one style placed centrally on it, bearing a cup-shaped stigma.

Fruit a globular capsule, wrinkled, opening loculicidally by five valves. Seeds numerous, embryo curved.

The fibre is extracted from the bark by soaking it in water and allowing the softer parts to decay.

C. OLITORIUS, L., is an annual herb like C. CAPSULARIS in many respects, but the leaves are ovate, lanceolate, serrate, prolonged into two sharp points at the base. The capsule is a narrow cylinder divided by five transverse partitions, and has a long beak. The plant is grown on a pot herb, and also like C. CAPSULARIS for the fibre, jute, contained in the bark.

GREWIA ASIATICA, L. This very variable plant is a small tree cultivated over most of India.

The leaves are alternate, stipulate, petioled, simple, obliquely cordate, irregularly toothed, pubescent on the petiole and under side of the veins, as also are the younger branches and parts of the plants generally. Five veins spring from the base, the mid-rib branching afterwards pinnately, the other two towards the margins, all joined by numerous parallel transverse veins, which are conspicuous on the lower side.

Flowers in short bracteate cymes. Sepals five. Petals four, free, linear oblong, yellow with a gland at the base. Stamens numerous on a raised thalamus. Ovary two to four celled, style single on top of the ovary with a small lobed stigma. Fruit a small drupe, entire or two-lobed.

CHARACTERS OF THE TILIACEÆ

This widely distributed family is found mostly in the tropics, and consists of trees, shrubs and herbs. The leaves are alternate, simple and stipulate with

three or five strong veins radiating from the base, and covered when young, like the young twigs and petioles, with soft yellowish pubescence.

The flowers are in cymes or panicles, small, polypetalons. Sepals and petals five each, stamens many, springing from a raised thalamus, ovary single with one central style and small stigma. Fruit a drupe or capsule.

It differs from the MALVACEÆ and STERCULIACEÆ in the stamens being generally free, not combined into a staminal tube, and springing from a slightly raised thalamus, and in the linear, two-celled anthers.

The Linden (or English 'Lime') so often grown in English gardens belongs to this family.

On the hills the commonest examples of TILIACEÆ are perhaps the different species of * ELÆOCARPUS. They are all trees with simple alternate leaves and can usually be recognized at once by the flowers being in axillary racemes and having fringed (or 'laciniate') petals, which give them a peculiar and unmistakable appearance. * E. OBLONGUS, Gærtu. sometimes called the Nilgiri olive, is planted in villages and near houses. Its leaves turn a brilliant red colour before they fall. In * E. FERRUGINEUS, Lot. the stamens number about twenty and each anther is prolonged above a thin awn. In other species they are more numerous, * E. SERRATUS, L. and * E. CUNEATUS, Wt. have thirty or forty, * E. TUBERCULATUS, Roxb. as many as seventy.

BERRYA AMMONILLA, Roxb. is a useful timber tree. Its wood known as Trincomallee wood, is of a dark red colour, and being very tough and springy is used for carts and for spear handles, and in the building of masula boats.

GERANIACEÆ

Examples:—

AVERRHOA CARAMBOLA, L., a small densely branched tree with alternate, exstipulate, imparipinnate leaves. Leaflets ovate or ovate, lanceolate, acute.

Flowers in panicled cymes, small, regular. Sepals five, petals five. Stamens ten, connected at the base, free above five without anthers. Ovary five-celled, with five styles, each with a capitate stigma. Fruit a five-lobed berry, three inches long. Seeds numerous yellow and with two-lobed aril.

The other species of this genus which is also cultivated in Indian gardens, A. BILIMBI, L. differs in the shape of the leaflets, which are narrower and longer in their pubescence, and in the seeds being without aril.

OXALIS CORNICULATA, L., a very common weed, with creeping stem, and alternate three-foliate, long-petioled leaves which have a pleasant acid taste, for which they are used in cooking, etc. Stipules adnate to the petiole, leaflets obcordate, pubescent.

Flowers two or more together on axillary peduncles, yellow. Sepals five, petals five, obcordate, stamens ten united at the base but free above. Ovary five-celled with five styles, and capitate stigmas. Fruit a loculicidal, oblong-shaped capsule, which bursts open suddenly along five vertical lines and ejects the seeds.

IMPATIENS BALSAMINA, L., the common single Balsam of our gardens, an annual herb. The leaves are alternate, simple, subsessile, oblanceolate, serrate.

Flowers on axillary pedicels. Sepals five, the posterior (which comes by twisting of the pedicel to hang down in front) spurred. Petals five, stamens five, anthers cohering as a sort of tubular box (syngenesious). Ovary five-celled. Fruit a loculicidal capsule

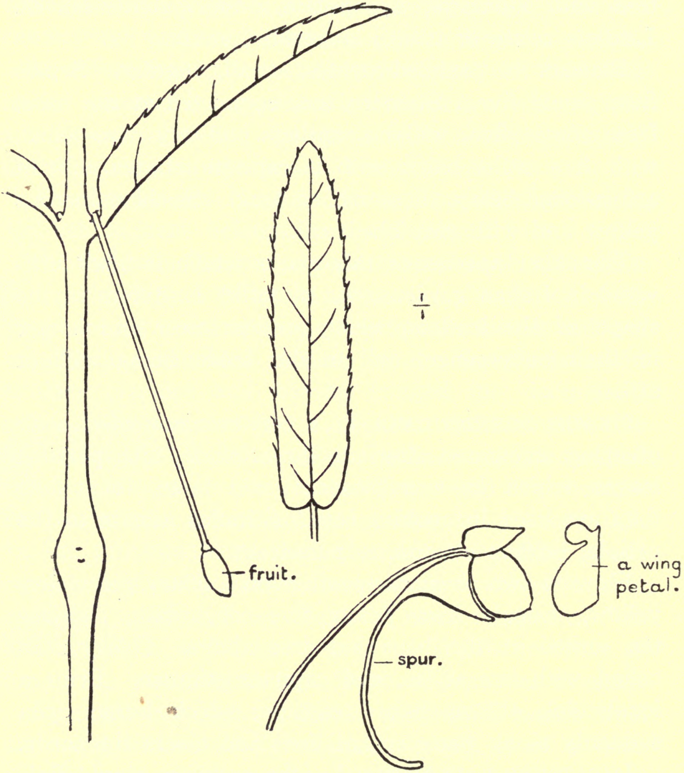

FIG. 73

IMPATIENS CHINENSIS, L.

which bursts open when ripe on the slightest touch, and turning as it were inside out, expels the seeds for some distance.

The best garden varieties differ in having 'double' flowers—flowers in which there are numerous petals and sepals, as with the case of garden roses. But they have been obtained by cultivation and selection from this original wild species I. BALSAMINA, L.

On the hills are many species of IMPATIENS. They have, as a rule, smooth rather translucent stems, and swollen nodes (fig. 73).

The garden Nasturtium (TROPŒOLUM) is another well-known member of this family. In it too the sepal is spurred. So it is in the garden Geranium (PELARGONIUM) but here the spur of the posterior sepal is adnate to (that is, grows welded with) the pedicel and is therefore hardly visible except as a slight thickening on one side of the latter. If the stalk be cut across the hollow space of the spur can be easily made out.

The true GERANIUM has perfectly regular flowers (without spur) and does not occur wild on the plains of South India, but one species G. NEPALENSE, Sw., grows on the hills.

CHARACTERS OF THE GERANIACEÆ

The GERANIACEÆ consist mostly of herbs, with alternate stipulate leaves, simple, or compound, or deeply cut, and often hairy.

All the parts of the flowers are in five's, five sepals, five petals, five outer stamens, five inner stamens, five cells to the ovary (five styles).

The fruit is nearly always a schizocarp or a loculicidal capsule containing many seeds, which are often forcibly ejected when it opens.

The flowers are mostly regular, but in some, e.g. TROPŒOLUM the garden Nasturtium, IMPATIENS the Balsam, and PELARGONIUM the garden Geraneum (in which it is adnate to the flower-stalk), one sepal is spurred, and in the Balsam there appear to be only three petals, because the lateral ones are united in pairs, as the 'wings'.

A very common well-known plant which belongs to a family very nearly allied to the GERANIACEÆ and is well known to every one because of the small spiny fruits, is TRIBULUS TERRESTRIS, L. a small weed with prostrate, hirsute, branches, pinnate leaves, and small yellow flowers.

It differs from the GERANIACEÆ in very little but the fruit, whose spines assist in dispersal.

TRIBULUS TERRESTRIS is a good instance of what was said in chapter ix on the nature and distribution of different types of plants (see p. 118). It occurs in open sandy places where there is not much moisture in the soil and the vegetation is not rich.

RUTACEÆ

Examples:—

CITRUS AURANTIUM, L., the Orange. The fruits of varieties of this tree are the different kinds of Orange. The 'Sweet Lime' is the fruit of another very similar species CITRUS MEDICA, L.

This well-known tree has spiny branches and alternate, exstipulate, one-foliate, leaves (see chapter xv,

the leaf has a joint in the middle, the distal portion being a leaflet, the proximal, the rachis).

Leaflet glandular with large translucent globules of oil, which give it its peculiar smell when crushed.

Flowers axillary, calyx cup-shaped, petals five, stamens numerous. Ovary many celled with one stout style and capitate stigma. Fruit a many-celled berry (each segment of the Orange being the equivalent of a cell). Seeds numerous immersed in a pulp of swollen hairs.

FERONIA ELEPHANTUM, Corr., the well-known 'Elephant' or 'Wood-apple' tree. A fair-sized tree, often with the leaves fascicled (in bunches) in the axils of spines (see p. 177), because on very short undeveloped branches. Leaves alternate, odd-pinnate, the rachis sometimes winged. Leaflets obovate, base cuneate, tip crenate or notched, otherwise entire, with numerous pellucid glands (which are easily seen, especially round the margin, if the blade is held up against the light). It is to the oil in these glands that the strong smell of aniseed is due.

Flowers in loose cymose panicles, appearing with the young leaves towards the ends of the branches, in the early part of the year. Calyx a small five-cornered flat plate. Petals five, free, ovate and curling backwards when fully open. Stamens ten, with large oblong anthers, and short filaments, the bases of which are dilated and slightly connected to form a villous cup round the ovary. Ovary at first of several, later on of one cell only, with no style but a very large oblong stigma which soon falls off. Some of the flowers with stamens only, others with an ovary

only, others again with both, (polygamous). Fruit a berry with woody rind, but edible pulp.

ÆGLE MARMELOS, Corr., the Bael tree, is also common and widely cultivated. Here also are strong straight spines, compound (three-foliate) leaves, with scented oil glands.

Flowers an inch or more in diameter, with small five lobed calyx, five petals, numerous stamens, short filaments and of large anthers. Ovary on a small disc, with several cells, a short style and large stigma. Fruit a berry with hard woody rind—the Bael fruit.

CHARACTERS OF THE RUTACEÆ

Comparing these three plants, we see that they have in common, a spiny tendency and alternate compound exstipulate leaves, which abound in oil glands, and are in consequence strongly scented. The flowers are in cymes or cymose panicles (not in spikes or racemes), have a small five (or four) lobed calyx, five free petals, ten or more stamens, a disc inside the stamens and an ovary of several, sometimes very many, chambers, with one style and stigma. Fruit a berry. Their classification into one family, the RUTACEÆ, is easily understood, and they are very typical members of it.

It is not a large family, but is almost confined to the tropical and subtropical parts of the world, and very common there. There are few herbs, most are trees and shrubs, with strongly scented simple or compound, alternate or opposite scented leaves. The fruit may be a berry or capsule or in a few instances is a drupe.

In gardens, especially on the hills, the common Rue, RUTA GRAVEOLENS, L., is cultivated, and is well-

known for its strongly smelling leaves. The ovary is deeply lobed at the top, and the fruit is a lobed capsule. It is the commonest species of temperate climates, but is not so like the rest of the family as the instances taken above.

Other common plants of the family are—

GLYCOSMIS PENTAPHYLLA, Corr., which has a small white flower and a small white berry.

* TODDALIA ACULEATA, Pers., with three-foliate leaves armed on the rachis and mid-ribs with curved prickles.

MURRAYA EXOTICA, L. and M. KŒNIGII, Spreng. with no spines or prickles.

ATALANTIA CEYLANICA with straight spines and one-foliate leaves like the Orange.

MELIACEÆ

Examples:—

MELIA AZADIRACHTA, L., the Neem or Margosa, a well-known road-side tree, cultivated in many parts of India for the oil obtained from the fruits.

Leaves alternate, exstipulate, pinnately compound. Leaflets lanceolate, acuminate, oblique at the base, coarsely serrate, glabrous.

Flowers small, in axillary panicles. Calyx with five obtuse lobes. Petals five, free, oblong. Anthers double as many, sessile on the inside of a staminal tube which is toothed at the top. Ovary superior, surrounded by a disc, three-celled. Style single, slender, stigma capitate. Fruit a drupe, fleshy with one hard stone containing an embryo, and oily endosperm.

MELIA AZEDARACH, L. is also common and often cultivated in India. It differs from the Neem in having bi- or even tri-pinnate leaves with irregularly toothed leaflets, in the lilac coloured and very fragrant flowers, and in the fruit which contains, as in most MELIACEÆ, one stone with as many as five cells and five seeds. The seeds are used to make rosaries.

CHARACTERS OF THE MELIACEÆ

This family consists mostly of trees. The leaves are alternate, exstipulate, usually pinnate, the leaflets more or less oblique at the base.

The flowers regular in large axillary panicles. Sepals and petals free or connate, stamens in the form of a tube, on the inside of which are the anthers.

Ovary surrounded by a disc, generally five-celled, with a single style and capitate stigma.

Fruit a capsule or drupe, berry, or capsule. Seeds in the latter case often winged (fig. 57, p. 256).

It includes several valuable timber trees, such as CHLOROXYLON SWIETENIA, D.C., the Satin wood tree, CEDRELA TOONA, Roxb., the Toon tree, SWIETENIA MAHOGANI, Jacq., the Mahogany of Central America.

WALSURA PISCIDIA, Roxb., has an ash-coloured deeply cracked bark, which is used in some parts for poisoning fish, for food.

RHAMNEÆ

Examples:—

ZIZYPHUS JUJUBA, Lamk. the common Lotus tree, which grows wild and cultivated all over India.

A straggling shrub or small tree armed with thorns, which from their position in pairs at the bottom of the petiole are clearly modified stipules (chapter xv). Leaves alternate, petioled, ovate, obtuse, coriaceous, entire or nearly so, green and glabrous above, covered beneath with a dense white or greyish-yellow coloured tomentum of matted branched hairs. Venation peculiar,—with three main veins from the petiole, the two lateral pinnate with strong branches towards the outside, and more numerous weaker ones on the inside; the centre vein also pinnate, branched strongly beyond the middle.

Flowers in axillary cymes, greenish-yellow in colour and about $\frac{1}{6}$ inch across. Sepals five, triangular, valvate in bud, the outer surface very tomentose, the inner smooth and green, with a small ridge. Petals minute alternating with the sepals, very concave. Stamens opposite the petals and each at first enclosed or hidden in one. Within the stamens a yellow lobed glandular disc, from the centre of which rises a minute two-branched style. Ovary below the disc, two-celled with an ovule in each cell. Fruit globose, fleshy with two stones (i.e. a drupe).

There are several other species of this genus ZIZYPHUS, common in South India.

Z. ŒNOPLIA, Mill., has flowers in axillary fascicles (or sessile cymes) like Z. JUJUBA, but the leaves are obliquely ovate, lanceolate and acute, with long brown silky hairs on the lower surface.

Z. XYLOPYRUS, Willd., has its flowers in peduncled, not sessile cymes. The branches inflorescence and fruits are covered with a greyish-white tomentum.

The leaves are broadly elliptical or orbicular in shape, and minutely serrate.

Z. RUGOSA, Lamk., common in Mysore and on the hills, has its flowers on spreading leafless branches, and there are no petals.

* RHAMNUS WIGHTII, W. and A., is common on the higher hills, as also the very spiny * R. DAHURICUS, Pall. (=R. VIRGATUS, Roxb.)

CHARACTERS OF THE RHAMNEÆ

The RHAMNEÆ are a family of trees and shrubs, found in all parts of the world. Many are armed with stipular thorns, and some climb with the help of these over other trees. The leaves are alternate, simple, coriaceous, with small stipules that fall off early, or with thorns. The flowers are small and greenish, in cymose axillary bunches, with five small sepals, five still smaller, concave petals, five stamens opposite to the petals and often covered by them, and a generally three-celled ovary more or less sunk in an intra-staminal disc. The fruit is a free or half inferior capsule or drupe, and the seeds have endosperm.

The chief thing to notice about the family is that the stamens are opposite to the petals, and that there is a prominent glandular disc within them.

SAPINDACEÆ

Examples:—

SCHLEICHERIA TRIJUGA, Willd., a tree grown often on road-sides, and found wild in dry forests.

Smallest branches green, angular. Leaves alternate, exstipulate, equally pinnate. Leaflets sessile, lowest

pairs the smallest, elliptic, entire, margin wavy, glabrous. Venation pinnate, secondary veins arched towards the margin.

Flowers small in long axillary spikes, shortly pediceled, staminate or bi-sexual. Calyx cup-shaped. Corolla absent, the whole space filled with a thick yellow disc from which arise the seven (six to eight) stamens. Ovary three or four-celled, with one style, and three-branched stigma. Fruit dry indehiscent. Seeds in fleshy aril, which is edible.

The wood is heavy and close grained, and of a red colour.

Sapindus trifoliatus, L., the Indian soap-nut tree. A tree with alternate, exstipulate, pinnate leaves. Leaflets (not as a rule, three as the name implies but four or more) elliptic or oblong, acuminate or emarginate, generally entire, coriaceous. Flowers in terminal or axillary, polygamous panicles. Sepals five, petals five, with scales fringed with long white hairs with a prominent concave disc surrounding the stamens. Stamens eight. Ovary three-lobed with one style. Fruit fleshy, the pericarp soapy. Seeds large, black, smooth and shining, with large white aril.

S. saponaria, L., the Soap-nut tree of the West Indies is also grown in India. The leaflets are lanceolate, acute.

CHARACTERS OF THE SAPINDACEÆ

The SAPINDACEÆ form a fairly large family scattered over the world, and are nearly all trees and shrubs, though there is one herb. The leaves are exstipulate, alternate, simple or compound. The flowers small more or less regular, the sepals and petals being

typically five, the stamens usually four or eight, i.e. fewer than the sepals or than double their number, and there is a prominent disc inside or outside them. The ovary has one style, the fruit is a capsule or a sort of berry. In many the seed has an aril, which in some entirely covers it.

FIG. 74
CARDIOSPERMUM HALICACABUM, L.

One of the commonest plants in India is DODONŒA VISCOSA, the Sanatta or Virâli, a bush with alternate, simple, entire leaves, that shine as if varnished, and flatwinged one-seeded pods (samara) in cymose bunches. The flowers are small, have large anthers but no petals, and the disc is not well developed.

NEPHELIUM LIT-CHI, Camb., is the Litchee tree, the edible part of whose fruit is the large fleshy aril.

CARDIOSPERNUM HALICACABUM, L., the herb referred to above has sensitive leaves and more or less climbing branches. Its name is taken from a white mark of the conventional heart shape on the seeds (cardium = heart, spernum = seed) by which it can at once be

recognized. On the hills, TURPINIA POMIFERA, D.C., and ALLOPHYLLUS COBBE, Bl., both trees with three-foliate leaves, are very common.

The 'Horse chestnut' (ÆSCULUS) and the Maple (ACER) belong also to this family.

ANACARDIACEÆ

Examples:—

ANACARDIUM OCCIDENTALE, L., the Cashew-nut tree. A small tree with short crooked trunk. Leaves alternate, simple, short petioled, obovate-oblong, entire, margins incurved, coriaceous, glabrous. Venation pinnate, with conspicuous secondary nerves.

Flowers small, in terminal panicled cymes. Sepals five, lanceolate acute. Petals five, linear oblong, acute. Stamens nine, slender, anthers round minute. Ovary immersed in a disc, one-celled. Style slender. Fruit kidney-shaped, and obliquely placed on a swollen receptacle (the end of the pedicel), the pericarp containing, when young, large chambers full of a very acrid juice. Seed one, embryo with two large falcate cotyledons, commonly eaten under the name cashew-nut. The pear-shaped swollen pedicel is the well-known rather acrid fruit.

The obliquely placed style and lop-sided ovary and fruit, point to the ovary consisting of but one carpel (as in the Bean, Pea, and Gram). The fleshy swollen pedicel is very unusual, but corresponds to the fleshy part of a pear or apple, the difference being that in them the ovary is inferior and enclosed inside the pedicel, in this it is superior and borne on top of it.

Mangifera indica, L., the Mango tree. The branches contain a sticky resinous juice, formed in special canals from which it exudes when they are broken. The leaves of the tree are alternate and vary a little in shape, they may be oblong, elliptic, or lanceolate, or even obovate, and obtuse, acute or acuminate, or mixtures of these, but are typically coriaceous and glabrous.

Flowers small, polygamous (i. e. unisexual or hermaphrodite) in large panicled, terminal on the branches. Pedicel jointed just below the flower. Sepals five, petals five, usually marked with reddish lines. Stamens five on a thick disc, one larger than the others, and with larger fertile anther. Ovary superior one-celled, with one slender style attached laterally to it, and thereby oblique. Fruit a drupe, lop-sided, containing a stone with one embryo.

The lateral position of the style, and the lop-sided shape of the fruit point to the ovary being composed of one carpel only (as in the Bean, etc.).

Odina wodier, Roxb. (Oothier-marum). Well-known for the fact that it sheds its leaves at the beginning of the year, and remains leafless all through the hot months, affording no shade at a time when shade would be most agreeable. It is thus a typical example of a deciduous tree.

The trunk is thick, the bark smooth, and marked even on thick trunks, with large scars. Just above many of the scars can be seen other smaller scars. There are the scars of the leaf and its axillary bud, which like the leaf scars are much larger than they were originally, because they have stretched latterly with the stretching of the bark (see p. 83).

The youngest branches and parts covered with stellate hairs. Leaves alternate, unequally pinnate, leaflets petioled, oblong-ovate, acuminate, entire, glabrous.

Flowers in slender drooping spikes of small cymes, unisexual, sepals, petals and stamens in four's, ovary one-celled. Fruit a kidney-shaped drupe, red-coloured, containing one stone and one seed.

CHARACTERS OF THE ANACARDIACEÆ

These three genera are good examples of the family ANACARDIACEÆ.

They are trees with resinous or acrid juice, alternate leathery, generally simple, exstipulate leaves. The flowers are small, regular, unisexual or bisexual or a mixture of these (polygamous). Round the ovary is a more or less cup-shaped glandular disc, and round this again stamens equal in number to the petals. The fruit is usually a drupe.

Another well-known species is—

SPONDIAS MANGIFERA, Willd., a deciduous tree with smooth grey bark, pinnately compound leaves, and large panicles of flowers. Leaflets elliptic-oblong, acuminate, entire. Fruit a drupe with yellow smooth skin (epicarp), rough-tasting flesh, and a stone with more than one cell but usually only one embryo, and well known as the Amra or Hog-plum.

PAPILIONACEÆ

The flowers of ERYTHRINA and CROTALARIA have already been described in chapter xvii. If these are

not available, flowers of the common Bean or Pea, or the Sweet-pea or Vetch may be taken, they will be found to be almost exactly like those of CROTALARIA except that the anthers are all of one shape, not of two as in CROTALARIA.

These are all members of the PAPILIONACEÆ, a family which is easier to recognize perhaps than any other, because of the peculiar form of the flower, with its 'standard', 'wings' and 'keel', and its one-celled pod (legume) (see figs. 30, p. 145, and 34, p. 148).

Except in some species of CROTALARIA and one or two other genera, the leaves are invariably compound with three leaflets (trifoliate), or many (pinnate), and in nearly all too the leaf stalk and the stalks of the leaflets have a conspicuous **pulvinus** at the base.

All the pulses (the introgenous, non-cereal seeds which are such valuable articles of food all over the world), the Grams, Peas and Beans, belong to this family. Clover and Lucerne are grown in cooler climates as green-fodder for animals. The English Laburnum (not the Indian Laburnum which belongs to the next family, the CÆSALPINEÆ) the Wistaria, Gorse, Broom and Lupin, are also members of the PAPILIONACEÆ, and well known for their flowers on the hills or in cooler countries.

BUTEA FRONDOSA, Roxb., is a common tree on the plains, and has large red flowers of which the keel is by far the largest, the standard the smallest part. CLITOREA TERNATEA, L., a twiner with usually five-foliate, pinnate leaves, has a large blue standard, and the flower hangs upside down so that the standard forms a sort of shelf in front of the flower. But

FIG. 75
CROTOLARIA JUNCEA, L.

practically all the family have a flower very like that of CROTOLARIA or the Pea, the standard erect and as large or larger than the wings or keel.

In other respects there is a certain amount of variation between the genera. Some like CROTALARIA have simple or digitately three-foliate leaves, and monadelphous stamens. In others, like the common Indigo (INDIGOFERA TINCTORIA, L.) the stamens are diadelphous and the leaves odd-pinnate (fig. 9 another species of INDIGOFERA). Then there are some which have the same sort of flowers and leaves, but the pods are jointed, and break between the seeds into one-seeded pieces, but don't dehisce in the ordinary sense of the word. But the largest group consists of those which, like Erythrina, have pinnately three-foliate leaves, and are for the most part climbers. This is the Bean or PHASEOLUS group. The Pea (PISUM) belongs

to a much smaller one, the Vetch or VICIA group, in which the leaves are evenly pinnate, and end in tendrils. This tendril is plainly homologous with the terminal leaflet of, say, the Indigo. To this group also belongs ABRUS PRECATORIUS, L. whose red and black seeds are used by jewellers as weights. PONGAMIA and one or two other genera form a small group by themselves, in that the pods contain only one seed when ripe and do not open. They are often winged (see chapter xxiv). All these have diadelphous, or in some cases monadelphous stamens, but there are also a few which have the stamens all free.

CÆSALPINEÆ

The commonest or best known examples of this family are on the plains, POINCIANA REGIA, Bojer. the Gold Mohur, and CÆSALPINIA PULCHERRIMA, Swtz. (the flowers of which have been described in chapter xvii), various species of CASSIA, e.g. CASSIA FISTULA, L. the Indian Laburnum, and the Tamarind TAMARINDUS INDICA, L. and on the hills, the common yellow flowered CASSIA TOMENTOSA, L. They are trees with pinnate or bipinnate leaves, and have in common that the flowers are more or less regular, and have five sepals, five petals, ten stamens arranged along the edge of the disc at the top of a slightly hollowed pedicel, and that in bud the lower petals are outermost, the upper (odd), petal being inside of all, not outside, as is the corresponding standard of the PAPILIONACEÆ.

In the Tamarind, SARACA and AMHERSTA, the calyx tube is long, with the disc and the sepals and petals (no petals in SARACA) at the end.

There is a good deal of variation in the number of stamens, but only because some are not developed. For instance, we find in CASSIA some species with three of the ten anthers small and without pollen, other species with only seven stamens (the other three not being developed at all). In AMHERSTIA NOBLIS, Wall., planted in Ceylon for its handsome large pink flowers, there are apparently only four sepals, three petals, and nine stamens and the Tamarind has but three petals and three stamens. But the presence of the posterior petal opposite the top sepal, shows that the latter is composed of two, fused together, and there are two short points representing the two anterior petals, and in the Tamarind seven others in place of the remaining stamens. So that these departures from the ordinary rules are due to the fusion of some, and the non-development of other missing parts. The flowers are really on the 5 + 5 + 10 + 1 plan.

One large genus—BAUNHINIA—has peculiar simple but deeply cleft leaves, like the spoor of a cloven-footed animal (goat, cow, etc.), but all the other CÆSALPINEÆ have pinnate or bipinnate leaves with prominent pulvinus.

In its pinnate leaves, one carpelled ovary and usually ten stamens, this family resembles the PAPILIONACEÆ, but the petals of a flower are more or less alike (there are no 'wings' and 'keel'), the stamens are nearly always separate (not mono- or dia-delphous), and the æstivation of the petals is 'ascending', the lower pair being outside and unfolding first, the uppermost, odd petal last. The very common shrub PARKINSONIA ACULEATA has already been referred to (chapter XV,

p. 179) as having the main rachis very short, only a stout thorn, so that the pinnæ appear to be so many distinct, pinnate leaves, in fascicles.

MIMOSEÆ

Examples:—

PITHECOLOBIUM DULCE, Benth. (Korukapuli). A small tree often used for hedges. The young branches are angular and marked by red lines running down them. The leaves have each two pinnæ, with two leaflets each; and stipules developed as thorns. There are often several leaves apparently at one node, on account of the non-development of the axillary branch on which they arise. In the young leaves, the two leaflets of each pinna, lie with their upper faces in contact, and their edges vertical. The two pinnæ are in their turn close together so that only the under surfaces of two of the four leaflets are exposed to the air, and only the edge to the midday sun. The leaf-scars and stipular thorns persist and in old stems, two or three inches thick, are often very conspicuous. The leaflets are obvate-oblong, and oblique, from one to two inches long.

Flowers in dense heads, half an inch wide, on short peduncles. Calyx very small, funnel-shaped. Corolla, funnel-shaped, its petals in bud valvate, and slightly connected above, but not at, the base. Stamens numerous united at the base, far exserted. Fruit one-celled, four or five inches long, and indented between the seeds and twisted when ripe.

PITHECOLOBIUM SAMAN, Gr., the Rain-tree. A tree with dark coloured stem and ascending branches often planted by the road side.

Young branches and leaves pubescent with yellow hairs, leaves alternate, bicompound, stipulate, the rachis swollen at the base and glandular between the pinnas. Pinnas opposite, pari-pinnate, the secondary rachides with glands on the upper side, and a distinct pulvinus. Leaflets with very short pulvinate stalks, obliquely ovate, the more distal larger, entire, glabrous on the upper side, the veins yellow pubescent on the lower, as are all the petiolules and rachides.

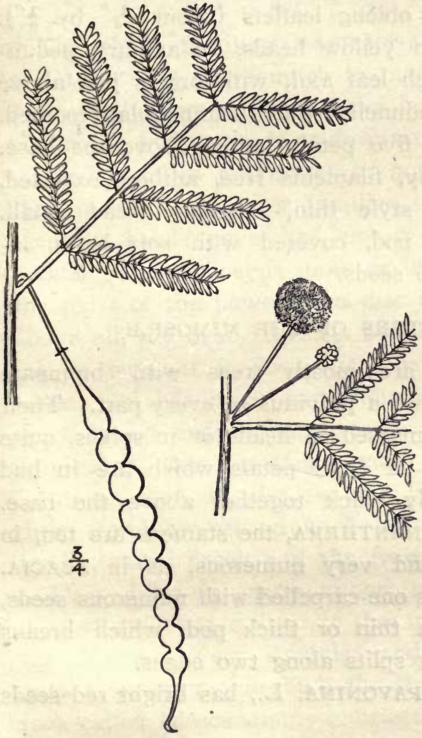

FIG. 76
ACACIA ARABICA, Willd.

Flowers in clusters nearly sessile on long peduncles, which are fascicled at the ends of the branches. Calyx tubular with five triangular lobes, valvate in bud. Corolla pink, tubular twice as long as the calyx, lobes five acute, valvate. Stamens very long, the filaments united below,

pinkish above, anthers small. Style slender. Fruit a dark coloured angular pod, with many seeds imbedded in a sweet sugary substance. A useful food in famine times.

ACACIA ARABICA, Willd. A small flat topped tree with straight greyish branches. Leaves alternate, with a pair of spines in the place of stipules, pinnate, the rachis with glands. Pinnas again pinnate with ten to twenty pairs of oblong leaflets (about $\frac{1}{16}''$ by $\frac{1}{5}''$). Flowers minute, in yellow heads, on axillary peduncles, several in each leaf axil, with bracts just above the middle of the peduncle. Calyx campanulate toothed. Corolla of four to five petals united above the base. Stamens very many, filaments free, anthers exserted. Ovary one-celled, style thin, stigmatic head small. Fruit a flat grey pod, covered with soft hairs, indented between the seeds.

CHARACTERS OF THE MIMOSEÆ

The MIMOSEÆ are mostly trees with bipinnate leaves, furnished with a pulvinus to every part. Their flowers are small, massed in heads or in spikes, quite regular, with five (or four) petals which are in bud valvate and usually stuck together above the base. In some as in ADENANTHERA, the stamens are ten, in others indefinite and very numerous, as in ACACIA. The ovary is always one-carpelled with numerous seeds, and the fruit is a thin or thick pod, which breaks open irregularly, or splits along two edges.

ADENANTHERA PAVONINA, L., has bright red seeds (see p. 267).

PARKIA BIGLANDULOSA, W. and A., is often grown and is well-known because of the flowers being massed

together in a long-stalked dense heads, looking like drumsticks.

MIMOSA PUDICA, L., is the very well-known sensitive plant, the pulvinuses at the base of leaves, pinnæ and leaflets being extremely sensitive and motile.

LEGUMINOSEÆ

The three families, PAPILIONACEÆ, CÆSALPINEÆ and MIMOSEÆ, have much in common. Their leaves are usually compound and the leaf-stalk and leaflets commonly fold upwards or downwards at night, moving on their swollen pulvinuses to a much greater extent than members of other families. The flowers are in racemes, heads or spikes, not in a cymose arrangements. The pedicel is more or less hollowed and has the parts of the flower on a disc round the top. And above all, the ovary consists of one carpel only, opening in fruit, if it does open, as a rule, along two edges, and has many campylotropous seeds, in which there is no endosperm, but an embryo with thick cotyledons that contain much nitrogenous matter (proteids, etc.), besides starch. For these reasons the three families are grouped together into one large family, called because of the fruit the LEGUMINOSEÆ.

They differ in many minor details, but the chief distinction between them, is that in the PAPILIONACEÆ, the flower is very irregular and the odd uppermost petal is outermost in bud, the æstivation being therefore called 'descendingly-imbricate'. In the CÆSALPINEÆ, the flower is nearly regular and the odd, uppermost petal is innermost in bud, the æstivation being

therefore 'ascendingly-imbricate', while in the MIMOSEÆ the corolla is quite regular and the æstivation of the petals is valvate, none overlapping.

MYRTACEÆ

Examples:—

EUGENIA JAMBOLANA, Lam., the Jamoon or Jambalam, a large well-branched tree well known on account of its fruit.

Leaves opposite, simple petioled, exstipulate. Blade ovale or oblong, shortly acuminate, entire, coriaceous, glabrous. Midrib prominent, lateral veins slender very numerous and close together, meeting in one running just inside the margin and parallel to it.

Flowers in small lateral panicles, calyx with small lobes (or sepals) or entire. Petals four, small round, greenish, and falling off together in one piece. Stamens numerous, the filaments bent inwards in bud. Ovary inferior two-celled. Style single, with small stigma. Fruit fleshy with one large seed (i.e. a one-seeded berry looking very like a drupe).

PSIDIUM GUYAVA, L., the Guava, a small tree cultivated in almost all parts of India on account of its fruit. Leaves opposite, simple, shortly petioled, exstipulate. Blade ovate or oblong, entire, glabrous above, slightly pubescent below, midrib and side veins prominent.

Flowers singly or in sets of two or three on short axillary peduncles. Calyx ovoid, and when the flower is opened, with four or five small lobes. Petals of the same number, round (i.e. without any claw), about

½ in. diameter. Stamens numerous, filaments slender bent inwards before the flower opens. Ovary inferior, enclosed in the calyx-tube, with two or more cells. Fruit a berry containing numerous hard angular seeds and crowned by the persistent calyx teeth.

* RHODOMYRTUS TOMENTOSA, Wt., the Hill-guava or Hill-gooseberry. A shrub with opposite leaves, which with the young branches are covered with a thick tomentum. Leaves elliptic, entire, coriaceous, glabrous above, tomentose beneath. Veins three to five, curved from the base.

Flowers in small axillary peduncled cymes, of one to three flowers, ovary inferior, calyx-tube tomentose, sepals five unequal. Petals five, mauve pink, with only a very short claw (stalk). Stamens many free bent down in bud. Ovary one to three-celled bud divided also transversely. Fruit a berry crowned by the persistent sepals.

* The EUCALYPTUS, of which several species have been introduced from Australia to the cooler parts of India, is too well-known to need description.

In one respect these trees are very peculiar. The young trees have square branches and opposite sessile leaves, on the older the branches are round and the leaves alternate, petioled, lanceolate and falcate. They are highly scented by roundish globules of oil. The flowers have an inferior ovary, round petals, and numerous long stamens which, in the bud, are curled-up inwards. The fruit which can be picked up in such large numbers under the trees, is a hard thick woody capsule, almost a woody-berry, but opening at the top.

Another well-known plant is PUNICA GRANATUM, L. whose fruit the Pomegranate, is also a berry. The epicarp or outer skin of the fruit is very tough, and the outer part of the seed is fleshy. In this flower we can see very well the characteristic way in which the filaments of the stamens are curled inwards before the flower is fully open, the inferior ovary, and on the fruit the crown formed of the persistent calyx. Changes take place in the ovary as it ripens into the fruit, whereby the seeds come to be borne not only on the central axis, or inner angles of the cells, but also on other parts of the cells. In other respects, however, in the opposite exstipulate, entire leaves, the inferior ovary, single style, round petals and curled-up stamens, the plant closely resembles the other MYRTACEÆ.

CHARACTERS OF THE MYRTACEÆ

The characteristics of the family MYRTACEÆ are now clear. They are nearly all trees or shrubs and with the solitary exception of the older trees of EUCALYPTUS, they have all got opposite, simple, entire leaves. In most the leaves are scented, the smell being due to drops of oil in special glands, which when the leaf is held up against the light, appear as small white dots (cf. the RUTACEÆ). The flowers are regular and have an inferior ovary, of one or two sometimes more cells. The sepals (or calyx lobes) are usually small, four or five in number, the petals roundish, four or five, and in many cases fall off soon after the flower has opened. The stamens are very numerous, have long sometimes red coloured,

filaments, which are at first bent inwards. These long coloured filaments to a great extent take the place of the petals in making the flower conspicuous (p. 236). The fruit is usually a berry with one or very many seeds, and has often at the top a crown (as in Guava and Rose-apple and Pomegranate) formed of the sepals.

Of other well-known or commonly cultivated members of this family mention may be made of * CALLISTEMON, R. Br., the Bottle-brush tree, whose flowers are crowded round the axis and have numerous straight red filaments, whence its name. It is a native of Australia.

MELALEUCA LEUCADENDRON, L., is cultivated for the oil—'Cajeput oil'—obtained from the leaves.

The dried flower buds of EUGENIA CARYOPHYLLATA, Thumb., form the well-known spice Cloves.

The Rose-apple or 'Malay-apple' is the fruit of another species, E. MALACCENSIS, L.

MELASTOMACEÆ

Example :—

MEMECYLON EDULE, Roxb. A small tree. Leaves opposite, shortly petioled, exstipulate, elliptic, entire, glabrous, lateral veins obscure.

Flowers in umbel-like cymose bunches, shortly peduncled in the axils of the fallen leaves, of the previous year's shoot, bright blue in colour and fragrant. Ovary inferior. Calyx cup-shaped with four shallow lobes. Centre (disc) of flowers depressed. Petals four, on the margin of the calyx-tube, roundish sessile (no claws). Stamens (also on the margin of

the disc) eight, four alternate with, four opposite to the petals. Filaments doubled down in bud, and still kneed after the flower has opened. Connective conspicuous and extending back from the anther as a horn-shaped body, the whole like the petals of a bright blue colour. Anthers opening by two slits. Ovary beneath the disc, one-celled with one style and capitate stigma. Fruit a one-seeded berry.

CHARACTERS OF THE MELASTOMACEÆ

This is a good example of the family MELASTOMACEÆ, which is akin to the MYRTACEÆ, but differs in some respects. It is a very large family with its centre in South America, but in India is practically (i.e. except for MEMECYLON) confined to the hills, where at elevations of 5,000 ft. and more, the different species of * OSBECKIA (e.g. O. LESCHENAULTIANA, D.C. with its large purple flowers) form a conspicuous feature of the vegetation. The flowers are, like those of the MYRTACEÆ, regular and have a deep calyx-tube enclosing the inferior ovary, with four or five sepals, the same number of petals, and of cells in the ovary, but of stamens double the number. The petals spring from the edge of the calyx-tube, with distinct claws and are contorted in bud. The anthers are very large curved and open by two pores at the top. At the bottom the connective is continued backwards as a spur,—the most characteristic and peculiar feature of the family. The venation of leaves is also characteristic, 3 to 5 main veins start from the base and curving so as to meet again near the open, are joined by numerous cross veins.

LYTHRACEÆ

Examples:—

LAGERSTRŒMIA INDICA, L., a shrub often grown in gardens for its beautiful pink flowers.

Leaves opposite, sessile or oblong, coriaceous, glabrous. Stipules very small.

Flowers in axillary cymose panicles, bracts deciduous, bracteoles smaller. Calyx-tube funnel-shaped, with six triangular teeth. Corolla polypetalous. Petals six, long-clawed crumpled in bud. Stamens many inserted near bottom of calyx-tube, filaments long curled up in bud. Ovary three to six-celled with one long bent style and capitate stigma. Fruit a loculicidal capsule. Seeds winged.

LAGERSTRŒMIA FLOS-REGINÆ, Retz., a fairly large tree with large mauve or lilac-coloured flowers, two inches or more in diameter in dense spikes, common in India both wild and cultivated.

It has angular branches and like L. INDICA opposite glabrous leaves (but shortly petioled, not sessile). The calyx-tube is ribbed and has six triangular spreading lobes and is covered with dense white tomentum. The petals being larger show their crumpled and wrinkled arrangement in the bud, better, and the fruit is an inch or more in diameter, and is very hard ('woody').

LAWSONIA ALBA, Lamk., the Henna or Mendi. A spiny shrub.

Leaves opposite, entire, lanceolate, narrowed at the base about an inch, less or more, in length. Flowers small, ¼ inch diameter, in large panicled cymes at the ends of the branches, very fragrant. Calyx-tube short

four-lobed. Petals four, obovate, wrinkled, inserted near the top of the calyx-tube. Stamens eight, in pairs between the petals and opposite to the sepals. Ovary free or four-celled with a single style and capitate stigma. Placentation axile. Fruit a globular capsule, with membraneous partitions. Seeds angular, sharp pointed, and tightly packed in the capsule.

CHARACTERS OF THE LYTHRACEÆ

These two genera are good examples of the family LYTHRACEÆ.

It consists of trees, shrubs and herbs, with opposite leaves, small stipules and generally cymose panicles of flowers. The calyx-tube is more or less deeply hollowed, the petals generally four or six inserted near the top of it, clawed, and crumpled or wrinkled when in bud. Stamens as many or twice as many, or very numerous, filaments long, inserted near the base of the calyx-tube. Ovary free, at the bottom of the calyx-tube, with two or more cells. Seeds many.

Other plants belonging to this family are—

WOODFORDIA FLORIBUNDA, Salisb., a shrub with long spreading branches covered in the hot weather with red flowers (the calyx is bright, the petals not very conspicuous).

PEMPHIS ACIDULA, Forst., which grows on the sea coasts all over the tropics of the East.

SONNERATIA ACIDA, Linn. f., another tree of much the same habit, forming part of the 'mangrove vegetation' of flat muddy seashores.

Various species of AMMANIA, e.g. A. PEPLOIDES, Spreng., A. ROTUNDIFOLIA, Ham., A. PENTANDRA,

Roxb., and A. BACCIFERA, L., herbs growing in damp places, paddy-fields, etc., all over India. Their flowers are so small as to be quite unlike the majority of the LYTHRACEÆ, and the petals are often absent. But they have the same sort of inferior ovary, single style, opposite leaves and definite stamens.

PUNICA GRANATUM, L., the Pomegranate, is placed by some in this family. It has already been described, as one of the MYRTACEÆ.

RUBIACEÆ

Examples: —

IXORA COCCINEA, L., a very common shrub, grown in garden for its red flowers.

Leaves opposite, almost sessile, elliptic, oblong or obovate, entire, coriaceous and glabrous. At each node, a stipule with long points joins one petiole to the other (hence called 'inter-petiolar').

Flowers in terminal, obviously cymose, corymbs. Calyx-tube small with four minute teeth. Corolla monopetalous, tube two inches slender, with four spreading elliptical lobes (petals) (fig. 47, p. 193) twisted in bud. Stamens situated on the mouth of the corolla tube, between the petals, anthers almost sessile easily detached and therefore often absent. Style long, reaching down the tube to the inferior ovary below, with two stigmatic branches. Ovary inferior two-celled. Fruit a small drupe, crowned by the calyx teeth, and containing two pyrenes.

* MUSSÆNDA FRONDOSA, L., on the ghats a very common shrub, easily recognized and familiar to every

one because of the large white 'leaves' (really enlarged calyx-lobes) which hang down among the brown flowers.

Stem round hirsute, leaves opposite, ovate, entire, narrowed to the short petiole, hirsute, with large interpetiolar stipules one on each side between the petioles of each pair of leaves.

Flowers in terminal cymes. Calyx-tube with five narrow spreading teeth. Corolla tubular below, above stellate with five spreading lobes, very hairy on the outside, smooth like brown velvet on the inside. Stamens five, borne on the corolla tube, anthers almost sessile, linear. Ovary two-celled, style slender, with two stigmas. Fruit a berry with many seeds.

FIG. 77. OLDENLANDIA UMBELLATA, L.

Varieties of this and other species are occasionally cultivated in gardens.

OLDENLANDIA UMBELLATA, L., a small diffuse herb, with blue flowers, very common on the plains among grass.

Stem four-angled, leaves opposite, linear oblanceolate, entire, glabrous, one-nerved. Stipules cup-shaped with bristles joining on each side the two leaves of a pair.

(There are frequently in the leaf axils in addition, one or two pairs of fully grown leaves, which are the leaves of the very short, otherwise undeveloped axillary shoots, which make the leaves appear fascicled.) (Fig. 78).

Flower in axillary umbel-like cymes. Calyx-tube cup-shaped with four minute teeth. Corolla monopetalous, tube short, lobes valvate. Stamens four, attached to the corolla tube. Ovary inferior two-celled, style short with two stigmas, ovules numerous. Fruit a capsule, opening loculicidally at the top with many seeds.

CHARACTERS OF THE RUBIACEÆ

Comparing these examples we find at once a similarity between them in the opposite leaves, interpetiolar stipules and regular flowers, with inferior two-celled ovary. These are the chief characteristics of the family RUBIACEÆ, the members of which can always be recognized as such by them.

It is a large family found chiefly in the tropics. In the colder parts of the world only one small section occurs. It comprises herbs, shrubs and trees. The leaves are always opposite, simple, entire, with interpetiolar stipules, i.e. the two stipules on each side coalesce into one.

The flowers are very regular, the corolla monopetalous four or five lobed, the stamens attached to the tube and of the same number as the lobes. The ovary inferior two-celled, with one or with many ovules in each cell.

The fruit varies; it may be fleshy with two pyrenes as in IXORA and the Coffee, or a schizocarp as

in HYDROPHYLAX, and SPERMACOCE or a capsule as in OLDENLANDLA, and CINCHONA, or a berry as in MUSSÆNDA and RANDIA.

The family is divided into two main groups, according as the seeds are one in each cell or many, and into smaller groups according to the aestivation of the corolla, whether twisted (convolute) or valvate, and to the nature of the fruit, and the position of the radical of the embryo, whether, in the fruit, it points upwards or downwards.

Other well-known examples of the family are—

GARDENIA—grown in gardens and often with double flowers.

* CINCHONA planted on the hills for its bark, from which quinine is extracted. The stipules fall off early so that at first sight the plant may not appear to belong to this family. The fruit is a capsule splitting open from below. The leaves are elliptic or oblong, acuminate.

* COFFEA ARABICA, L., the Coffee. The fruit is a berry with two seeds enclosed in 'parchment' (p. 244). It is the seeds which are roasted and ground.

MORINDA CITRIFOLIA, L., and M. TINCTORIA, Roxb., the Indian Mulberry (Togari-wood), cultivated over the hotter parts of India for the dye obtained from the roots. Botanically speaking this genus is chiefly interesting because of the coalescence of the fruits of a cluster of flowers into one mass forming a multiple or collective fruit of several drupes.

SPERMACOCE HISPIDA, L., a very scabrid and hairy procumbent herb, which is common enough on the plains of India.

Hydrophylax maritima, L., a creeping succulent herb with round thick glabrous branches, and small fleshy flowers, very common on sandy seashore of South India.

COMPOSITÆ

Examples:—

Helianthus annuus, L., the common Sunflower.

If we examine the flower of any of the many varieties of this plant, we shall find on the outside at the base, a number of lanceolate acute bracts imbricated one above the other. Above them come the yellow **rays** of the flower-head, while the middle or **disc** of the flower-head is made up of a number of small tubular flowers or **florets** as they are usually called.

If we examine a large flowered kind, we shall see quite clearly that the innermost central florets open last, the outermost (those next the rays) first, and that the first thing visible in the newly opened floret is a dark brown cylindrical structure, tipped with yellow, from which in a day or two emerges the two-curled, branches of a style. In the outermost of the disc florets there may be only the two stylar branches. The dark brown structure consists of five anthers joined together, as can be easily made out in a still unopened floret by splitting it open with a needle. The filaments are free of each other, but united below to the corolla tube, and each anther has at the top a thin brown scale. Clasping each disc floret there is a large pointed scale.

The yellow rays are also florets, though differently developed from those of the disc, for the corolla is

expanded on one side; but their identity as florets is clearly shown by their likeness to the others in the style and inferior ovary, even though the stamens are absent.

We see then that the whole flower-head is a composite structure made up of a large number of florets.

The florets are flowers, those of the disc complete in everything but the calyx, those forming the rays without stamens or perhaps even styles.

The whole head is termed a **capitulum,** the green bracts outside are called the **involucre,** or the 'bracts of the involucre,' and the expanded end of the stalk, on which the florets are set, is called the **receptacle.**

The anthers are **syngenesious,** forming a tube round the style, and open on the inside, so as to shed their pollen into this tube. The small triangular flaps, at the tops of the anthers are continuations of the connectives, and combined together they form at first a lid to this tubular box. The style is at first much shorter than the stamens but growing rapidly in length, with the age of the floret, pushes out the pollen in front of it, at the end of the anther-tube (which is the reason for the small tufts of pollen one sees on the newly opened florets), and bees very quickly remove this pollen. After a while the style still growing, protrudes beyond the anthers and its two branches separate and display their inner, stigmatic, surfaces, ready to catch any pollen that may be brought by bees, or may fall on them, and later on curling downwards, pick up pollen that has fallen on the corolla tube.

If you watch bees at work you will generally find that they alight on the outer edge of the flower-head

and work inwards towards the centre, in this way, the outer, older florets, often catch on their styles, pollen brought from a different flower-head and a different plant.

This is a beautiful instance of a special mechanism for offering pollen to bees and for receiving later on from bees any they may in turn bring from some other plant, or failing this for securing pollen that may have fallen from the anther of the same flower. And it is one which can be made out very easily, at every stage, in one flower-head.

COSMOS KLONDYKE the yellow Cosmos of our gardens, and COSMOS BIPINNATUS, the pink and white Cosmos, have flower-heads built up in the same way, but different in details. The bracts of the involucre are in two rows, the lower outer row green and spreading, the inner scarious and erect.

GAILLARDIA, COREOPSIS, ZINNIA and many other common garden plants, having florets massed together in one head, belong to this family. The cultivated Chrysanthemum differs in having many circles of ligulate or ray flowers, but this is the result of cultivation.

Some of the family e.g. VERNONIA, EUPATORIUM, CENTRATHERUM and the Thistle have no ligulate florets, all being alike tubular, so that the flower-head has no rays.

There are others such as NOTONIA, SENECIO, *TARAXUM the Dandelion, Chickory, LAUNEA (fig. 25) and * PICRIS in which all the florets are ligulate, so that there is no separation into disc and rays.

CHARACTERS OF THE COMPOSITÆ

All these plants are alike in the florets being imperfect by the non-development of the calyx, and massed into a head with an involucre below; in the inferior ovary, which ripens into an achene; in the syngenesious anthers with connective produced at the top; and in the style with its two stigmatic branches.

There is in nearly all cases no difficulty at all in recognizing any member of this very well-marked family. Most have alternate leaves though one or two have them opposite. A comparatively few only have scales between the florets, the receptacle being generally naked.

In many genera there develop at the top of the achene where the calyx should be, a circle of hairs, called the **pappus,** which makes it buoyant and easily carried by wind (p. 261). In some a few scales or sharp points are developed, in others nothing at all.

The nature of the flower-heads, whether all the florets are the same and tubular, or some tubular with rays of ligulate ones round, or again all ligulate, as in the instances given above, are points of importance; as also are the presence or absence of scales between the florets, and of a pappus on the fruit, and its nature whether simple as SENECIO, or feathery as the Dandelion. The anthers may be produced in tails at the base as in *CENTRATHERUM and VERNONIA, or be rounded as in the Sunflower, ASTER and *AGERATUM. The arms of the style may be short or long, blunt or pointed. The bracts of the involucre may be all of one length and in one circle as in EMILIA

and NOTONIA, or imbricated in several rows, the outer shorter than the inner as in the Sunflower. They may be green like leaves, or scarious and coloured as in *ANAPHALIS and *GNAPHALIUM the Cud-weed, or have scarious brown tips, and in some, e.g. the Thistle, they are spiny. All these characters are used to distinguish the genera from each other and to class them into separate tribes, and should therefore be noticed when examining a plant.

The family COMPOSITÆ is the largest order of flowering plants and members of it are found in all parts of the world. It is also in many respects the most perfect and most fully developed of all, for the arrangement of the flowers in heads often with brightly coloured rays of ligulate florets, and the mechanism by which the pollen is offered to passing insects, are very simple but very effective aids to cross fertilization (see p. 235), while the pappus or the hooked bristles which so many achenes of the COMPOSITÆ have, are undoubtedly the cause of rapidity with which some species spread.

Most are herbs, but there are some trees and shrubs, and on our hills are some species of SENECIO which straggle over other shrubs.

CUCURBITACEÆ

Examples:—

CUCUMIS MELO, L. The Melon.

A coarsely hairy herb, with ribbed hollow stems climbing (if it is allowed to climb) by tendrils.

Leaves alternate, exstipulate, petioled, orbicular or reniform, five-lobed.

Flowers unisexual, monoecious (both kinds on same plant). Staminate flowers in clusters, ovary flowers solitary in the axils of the leaves. Calyx-tube campanulate, five-lobed, inserted on the calyx-tube. In the staminate flowers stamens three, attached below the mouth of the calyx-tube; anthers three, one one-celled, two two-celled, bent back on themselves; filaments produced in a crest. In the ovary flowers, the ovary inferior with short style and three stigmas, one-celled, with three parietal placentas. Fruit a berry with leathery rind (pericarp) and very thick watery placentas which form the edible part of the melon.

The Cucumber is the fruit of a very similar species, C. SATIVUS. Other commonly cultivated or well-known plants belonging to this family:—

CUCURBITA MAXIMA, Duch. is the Common gourd. C. MUSCATA, Duch. the Musk melon and C. PEPO, L. the Pumpkin. This genus differs from Cucumis in the corolla tube being longer, about half of the whole length of the flower.

CITRULUS COLOCYNTHIS, Schrad. the Water-melon plant differs from CUCUMIS in the staminate flowers being borne singly not several together in an axil, and in the tendrils being branched. The leaves of this species are much more deeply lobed.

LUFFA ÆGYPTICA, Mill. has a very long narrow fruit. The flowers differ from those of CUCUMIS and CITRULUS in the stamens being inserted nearer the mouth of the calyx-tube and the anthers being less closely connected.

TRICHOSANTHES ANGUINA, L. the Snake gourd, has fimbriate almost free petals.

LAGENARIA VULGARIS, Ser. the Bottle gourd, has its petals entire, and the anthers included in the calyx-tube.

CEPHALANDRA INDICA, Naud. the Scarlet gourd, has flowers like CUCURBITA, but white not yellow, and the tendrils are simple not divided.

CHARACTERS OF THE CUCURBITACEÆ

All these are members of very clearly marked and easily recognized family, the CUCURBITACEÆ. They are all climbing herbs with hollow stems and simple or divided tendrils, the homology of which is obscure, for they do not appear to take altogether the place of leaves or axillary branches, but seem to be partly branch, partly leaf-structures. In nearly all species the leaves, and plant generally, are covered with coarse stiff hairs.

The leaves are alternate, petioled with cordate or kidney-shaped base, simple, lobed or more or less divided (palmately).

The flowers are regular, unisexual, monoecious or dioecious, yellow or white, with a long or short calyx-tube and five-lobed corolla (see however the concluding chapter). The stamens occupy the centre of the staminate flower and have thick filaments, two much thicker than the third. The anthers are in most genera doubled back on themselves, one one-celled, two two-celled, so that there are five cells in all.

But since in one genus there are five distinct stamens each with a one-celled anther, we must, regard the stamens in CUCUMIS and other similar genera as really five, of which four are united into two. The

ovary in the ovary flowers is inferior, with three parietal placentas which may almost meet in the centre, and constitute the watery flesh of the fruit, a berry (p. 245), peculiar in having a thick tough rind. The seeds are very numerous and flat, and in some cases there is formed on the hypocotyl of the germinating embryo, a projection which holds one half of the seed coat down so as to allow the cotyledons to be pulled out more easily (p. 50). There is no endosperm.

The family occurs mostly in the warmer parts of the world.

* ERICACEÆ

This family is quite absent from the plains, but in the hills is represented by GAULTHERIA and RHODODENDRON.

RHODODENDRON ARBOREUM, Sm. is a well-known tree occurring on the higher, bleaker, slopes of the hills. The bark is very thick and to this is probably due the presence of the tree in those open moorlands where periodic grass fires kill out trees less well protected.

Leaves alternate, oblong, rough, with prominent veins and incurred margins and covered with a silvery and brownish tomentum.

Flowers massed in almost sessile, dense branches. Corolla monopetalous, campanulate, five-lobed, pink or red with dark patches inside at the base. Stamens ten, separate from, not attached to, the corolla tube, their anthers each with two small tails and opening by two pores at the upper end, not by slits. Ovary five or more celled with a single style; fruit a

loculicidal capsule containing numerous seeds on axile placentas. The flower is thus very regular.

GAULTHERIA FRAGRANTISIMA, Wall. is a small shrub with much smaller white flowers. Leaves also alternate, entire and thick, with on the underside numerous black dots, from which black hairs sometimes spring. If crushed the leaf gives out a peculiar pleasant scent because of the oil ('oil of Winter green') which it contains.

Flowers again quite regular, with five lobes to calyx and corolla, ten free stamens, tailed anthers, and a five-celled ovary.

CHARACTERS OF THE ERICACEÆ

These two examples show very well the characters of the order,—the alternate leaves, the regular flowers, the stamens unattached to the corolla, the tailed anthers and the superior five (or more) celled ovary. The chief home of the family is S. Africa where the heaths, plants with short, narrow, linear leaves, are a feature of the vegetation. Heather and Ling are the European representatives.

* VACCINIACEÆ

There is another family the VACCINIACEÆ which differs from the ERICACEÆ practically speaking only in the ovary being inferior and in the anthers not being tailed.

It is represented on the hill by VACCINIUM LESCHENAULTII, Wt. a small tree, with stiff erect ovate leaves, small pink bell-like flowers, anthers prolonged into tubes, and black or purple berries.

MYRSINEÆ

Examples:—

EMBELIA RIBES, Burm. a scandent shrub.

Leaves alternate, exstipulate, simple, with glands or resin passages in the blade and on the petiole. Blades elliptical-acute, with cuneate base, entire, coriaceous and glabrous.

Flowers small, unisexual or bisexual (polygamous), in axillary panicles. Calyx five-lobed. Corolla deeply five-lobed (or petals free) white. Stamens five attached to the corolla and opposite the lobes. Ovary superior one-celled, with a free central placenta (not reaching to the top). Fruit globose one-seeded.

MAESA INDICA, Wall. a shrub, very common especially on the hills. Leaves alternate, lanceolate, ovate or elliptic, acute, dentate, glabrous. Flowers in short axillary racemes, calyx of five small teeth, more or less inferior. Corolla monopetalous, campanulate, with five imbricating lobes. Stamens five epipetalous. Ovary, half inferior, one-celled with a short style, ovules on a free central globular placenta. Fruit a berry with numerous seeds.

CHARACTERS OF THE MYRSINEÆ

The MYRSINEÆ are a family of Tropical trees, with alternate, simple, exstipulate leaves, and small regular flowers. The corolla tube is short, with the stamens standing on it and opposite its lobes (not alternately as one might expect). The ovary is one-celled and has a round central placenta over the whole of which are set the numerous ovules, and which does not reach to the top, i.e. is free.

Perhaps the most interesting plant of the family is ÆGICERAS MAJUS, G. which grows in the low mud flats of the sea-coast, and is distinguished by having stretching out from the soil all round it, upright roots of a spongy texture, which appear (like the spongy petioles of NYMPHÆACEÆ), to provide for the under-ground roots that change of air which the water logged state of the soil renders difficult (p. 104).

SAPOTACEÆ

Examples:—

MIMUSOPS ELENGI, L. a tree often grown in Indian gardens for its sweet-scented white flowers. The bark is rough, the small branches very numerous and covered at the ends with rust-coloured tomentum. All parts abounding in latex. Leaves alternate, shortly petioled, simple, elliptic acuminate, entire, coriaceous, glabrous and shining. Venation pinnate, the secondary veins very slender and nearly at right angles to the midrib.

Flowers on axillary pedicels, fascicled. Sepals in two whorls, the outer valvate, the inner imbricate. Corolla monopetalous, rotate, with very short tube and lobes in three whorls of eight each, the inner whorl forming a cone over the stamens. These are the corolla-lobes proper, the two outer whorls being in reality scales developed on their backs. Stamens eight, interspersed with a whorl of fringed and hairy staminodes, anthers linear, connectives produced beyond them. Ovary in the centre tomentose, eight-celled, with a single stout style centrally placed. Fruit a berry, one-celled, with one seed.

ACHRAS SAPOTA, L. the Sapodilla-plum, a native of Tropical America, cultivated in India.

Leaves alternate, simple, petioled, elliptic or obovate, shortly acuminate, entire, coriaceous, glabrous. Venation pinnate, the midrib very strong, the veins very numerous and slender. Flowers on axillary pedicles of an inch in length and similar to those of MIMUSOPS ELENGI, L. but with fewer parts and not opening widely.

Calyx and corolla six-lobed; staminodes six, petaloid; stamens six; ovary twelve-celled, tomentose, style stout. Fruit globular like an orange, with thin brown skin and persistent calyx lobes.

CHARACTERS OF THE SAPOTACEÆ

The SAPOTACEÆ are a family found only in the Tropics. They consist of trees and shrubs, with alternate, entire, exstipulate leaves, and the young parts covered by a brown tomentum.

The flowers are curious in that the sepals are mostly in two whorls. The petals and stamens both alternate with the sepals, the staminodes being the outer whorl. In some genera there are scales on the inside of the corolla-lobes, in others (as MIMOSOPS) on the outside.

APOCYNACEÆ

Examples:—

VINCA ROSEA, L. a herb very commonly grown in gardens and in dry sandy places, for its white or purplish-pink flower. Stem round, green or purplish. Leaves opposite, shortly petioled, elliptic or obovate,

mucronate, entire, coriaceous, glabrous. Venation pinnate, side veins numerous, pointing forwards.

Flowers in pairs in the axils of the leaves. Calyx with five long slender sepals. Corolla salver-shaped, the tube long and narrow, the mouth contracted, and almost closed below by a fringe of hairs, the limb spreading in five broad petals. Anthers five, sessile on the inside of the corolla tube; the pollen of each anther ejected as two yellow masses, which however afterwards disintegrate. Ovary of two carpels, joined in one style but free below, with a large green gland on either side. Stigmatic head shaped like an hourglass, of two superimposed discs with a fringe below. Fruit of two follicles with numerous small seeds.

The Periwinkles (V. MAJOR, L. and V. MINOR, L.) of England belong to this same genus.

NERIUM ODORUM, Soland. a shrub very commonly grown in Indian gardens for its sweet-scented pink flowers.

Leaves opposite or in threes, narrow elliptic or lanceolate, acute, coriaceous, glabrous. Margin revolute, venation pinnate, the midrib very strong, the veins slender, numerous and straight.

Flowers in terminal cymose panicles, bracteate. Sepals five, lanceolate, acute. Corolla monopetalous, ventricose with spreading limb, the lower half of tube narrow, upper inflated. Lobes of limb five, oblique rounded convolute overlapping. Mouth with circle of filamentous projections. Stamens five, anthers sessile on the throat of the corolla, sagittate, adhering to the stigma and prolonged above into five long hairy and twisted filaments, the pollen as in VINCA, coming out

of the anthers as two yellow masses. Ovary four-lobed, disc, annular small, style single. Fruit of two erect narrow follicles, seeds with a tuft of caducous hairs.

CHARACTERS OF THE APOCYNACEÆ

The APOCYNACEÆ are a large and very important family, mostly twiners, which play an important part in tropical forests. Many of them contain in the stem and leaves, a thick white sticky juice (latex). The leaves are simple, entire, usually opposite but in some cases alternate. The flowers regular, on the five plan, the corolla lobes convolute (twisted) in bud, the anthers almost sessile on the corolla tube, often included inside it, and sometimes adnate also to the stigmatic head of the style. The ovary consists of two free or united carpels, but always has one style only, and ripens into two follicles or sometimes a berry. In some the seeds have a tuft of long white hairs.

Other common garden plants belonging to this family are—

ALLAMANDA CATHARTICA, L. a shrub with milky sap. Leaves whorled, elliptic, acuminate. Flowers large, yellow, funnel-shaped, the lower half of the corolla tube narrow, the upper wider; limb of five spreading lobes, convolute in bud. Throat of tube closed by the five sagittate anthers, and a hairy growth just above them. Style very slender, the stigma large, not joined to the anthers.

THEVETIA NERIIFOLIA, Juss. Sap milky, leaves alternate (spiral), narrow or lanceolate with strong midrib. Flowers in axillary cymose panicles. Corolla tubular below with long, oblong lobes, convolute in

bud. Anthers small sessile, free of the stigma with tufts of hairs on the corolla above and below, completely closing the throat. Style slender, stigma larger. Disc a large yellow ring.

PLUMERIA ALBA the Frangipani (fig. 27, p. 142), and P. ACUTIFOLIA (fig. 26) the Pagoda tree are well known. They are deciduous, and flower before or with the new leaves. The branches are very thick and the leaf-scars large. Latex copious.

ASCLEPIADACEÆ

Examples:—

CALOTROPIS GIGANTEA, Br. a very common plant growing in waste places, on the seashore, on dust heaps near villages, on almost any kind of soil and in almost any bit of uncultivated land on the plains of India.

It is a shrub with rather soft round (terete) branches and opposite almost sessile, oblong-ovate, entire, rather fleshy leaves. The whole shoot, except the flowers, is covered over with a peculiar white or yellowish powder or fluff, which comes off very readily when touched, and a thick white sticky juice ooses out if a branch is broken or a leaf plucked.

The flowers are in terminal, irregular umbels, of a cymose nature, and white or purplish in colour. The sepals small about one-eighth inch long, and forming a five-lobed stellate calyx. The corolla (not enclosed by the calyx except in the very youngest stages) monopetalous, but deeply divided into five oblong-ovate or triangular segments, very smooth on the outer side, velvety on the inner.

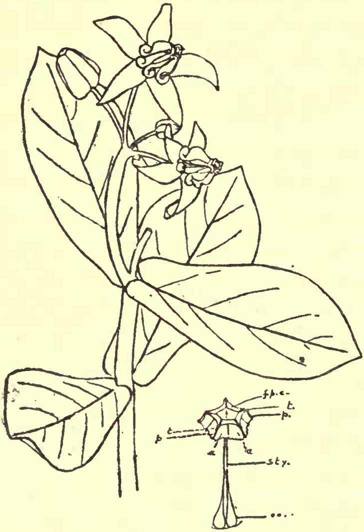

FIG. 78.

CALOTROPIS GIGANTEA, Br.

The Madar

f.p.c. flap of connective
t. translator
p. pollinium
a. anther
st. styles
ca. carpels

In the centre is a large structure formed of five radiating buttresses, surmounted by a thick five-angled plate. At each angle of this plate there is a little brown or black speck, which, if removed by a needle or a pair of forceps, is seen to have attached to it two very thin flat yellow bodies. These yellow flakes are formed of pollen, and called **polliniums.** The whole structure is hollow, and inside it are two ovoid carpels with separate styles which unite just under the thick five-angled plate, in which they end. Each side of this plate in continued upwards as a little flap which folds over the upper edge. If a needle or small knife be inserted under this flap and pressed outwards, the whole side can be pushed off exposing a yellow pollinium at each end (see p. 225).

Here is something quite different from anything we have come across in flowers. Now in a flower with five

sepals, petals five and five stamens, the latter usually stand alternately with the petals, and this is the case here. Each of the five buttresses (collectively known as the **corona**) is a development on the back of a stamen, a much enlarged filament in fact, and the thick five-angled plate is formed of the five anthers joined to each other and to the combined heads of the two styles. A much less developed connexion between anthers and stylar head we saw occurs in some of the APOCYNACEÆ, e.g. in NERIUM. The flaps are extensions like those on top of the anthers of the COMPOSITÆ, of the connectives which are here expanded laterally, so that the pollen sacs of an anther are separated by about one-sixteenth of an inch, but lie each very close to a pollen sac of the next anther on either side. And the pollen in each sac instead of separating into distinct grains, forms one flat yellow pollinium. The polliniums of two adjacent anthers become connected by a special bit of tissue, the black speck referred to above, which because it carries them away with it when removed, is called the **translator,** or sometimes the **gland.**

The curious central structure of this flower is thus seen to be made up of the same parts as those of an ordinary flower, but modified and fused into one mass.

The fruit of this plant is a large inflated follicle, formed of one of the carpels, and contains a number of flat seeds tightly packed together, and each with a tuft of long silky hairs.

*CEROPEGIA ELEGANS, Wall. the Lantern flower. Like most of the family it is a twining herb with opposite leaves and a flexible stem.

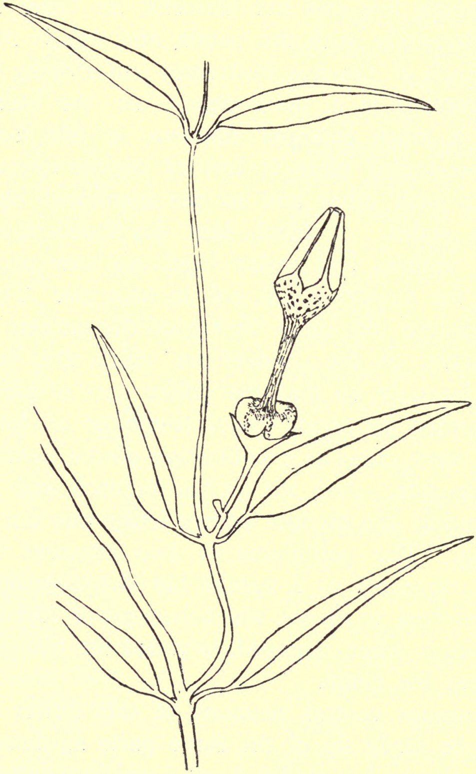

FIG. 79

CEROPEGIA ELEGANS, Wall.

The leaves are lanceolate, acute, about two inches long, with a petiole of half an inch. The flowers occur singly or in cymose pairs (one opening before the other) in the leaf axils, with pedicels of one inch, with five linear sepals rising from a membraneous cup.

The corolla is utterly unlike that of any other flower, and consists of an inflated base connected by a narrow tube to the top part, which is formed of five pairs of oblong lobes, each lying flat against the adjacent of the next pair, on either side, and all joined together at the top, so as to leave five elliptical spaces like the windows of a lantern. Inside and at the bottom of the corolla will be found the central structure of stylar-head and stamens, fused together as in CALOTROPIS, and surrounded by a five-toothed membraneous cup, blotched with purple like the corolla. This is an outgrowth of the corolla and termed the coralline-corona. Inside this will be seen, five rather long, green rods leaning slightly towards the centre, and under each of these a stamen with its two brown anther lobes. From the position of the anther we may conclude that each rod is a development on the back of the stamen, like the vertical curved buttress in CALOTROPIS, and corresponds to it. The rest of the structure is too minute to be easily made out, but the two flowers are built up on much the same plan, only that there is here no extension of the connective as a flap lying on the stylar-head.

CHARACTERS OF THE ASCLEPIADACEÆ

This plant and CALOTROPIS are very good examples of the family ASCLEPIADACEÆ, and the latter flower being large is the one most easily studied. Most of the family are twining herbs or shrubs. There is always a white sticky juice (sticky because it contains rubber), the leaves are opposite, simple, entire and exstipulate. The inflorescence is a cymose umbel,

terminal or axillary, the flowers regular, with five sepals, five petals, and five stamens connected together and to the stylar-head, and usually with outgrowths forming the staminal-corona. There are two free carpels, which in fruit form follicles and the seeds are flat with a tuft of hairs (fig. 58).

The family is a fairly large one and almost exclusively tropical, being unknown wild in temperate regions. There are, of course, differences between the genera, the most important of which is in the position of the translator, which may be at the top so that the polliniums hang down as in CALOTROPIS, or at the bottom so that they are erect, or so that they lie horizontally. In some genera there are twenty polliniums, i.e. two to each anther lobe. There are great differences too in the form of the corona, which may be single as in CALOTROPIS or double. In the family are also included genera, like CRYPTOSTEGIA, in which the filaments are free, and the pollen masses granular not waxy, but which are in other respects much more like this family than to the closely allied APOCYNACEÆ.

The Wax-flower, HOYA CARNOSA, Br., is often cultivated for its flowers. The corona is a very large, thick, stellate, white mass. Another species, * H. OVALIFOLIA, W. & A., grows wild on the hills.

STEPHANOTIS is a well-known garden plant, belonging to this family, as also is CRYPTOSTEGIA which has giant bell-shaped flowers.

CARALLUMA and SARAOSAEMMA have no leaves but instead green branches, a typical adaptation for a dry climate. Compare EUPHORBIA TIRUCALLI, L. (p. 379) and the Prickly-pear (p. 181).

CONVOLVULACEÆ

Example:—

IPOMŒA. A large number of species are grown in gardens for their flowers, some white as the Moon-flower which opens in the evening, some red, most purple or blue.

These are all twining herbs with alternate, long, petioled, entire or lobed, and for the most part cordate, leaves.

The flowers are axillary, generally in peduncled, cymose inflorescences. Calyx cup-shaped, five-toothed. Corolla campanulate or funnel-shaped, entire, marked on the outside with five lines of a darker or lighter colour. Stamens five generally of different lengths, attached to the base of the corolla tube. Ovary superior two-celled with one style, and two globose stigmas. Fruit a globose capsule, opening in various ways. The dark areas in the corolla are due to the peculiar way in which it is folded in bud, i.e. inwards along five lines and then twisted, the portions exposed to the light while in the bud stage being of a different colour from those inside. This æstivation is termed induplicate-convolute.

IPOMŒA is a very characteristic genus of this family, and almost any species will do as a type.

CHARACTERS OF THE CONVOLVULACEÆ

The CONVOLVULACEÆ comprise shrubs and herbs, for the most part twiners. The leaves are alternate, exstipulate, and usually entire and cordate. The inflorescence is cymose, the corolla monopetalous, folded and

twisted in bud, and generally funnel-shaped. The stamens are five, the ovary superior two-celled, with two ovules in each cell. The fruit is in some genera fleshy, but in most a capsule which opens irregularly, or is circumciss. The cotyledons are usually long and rolled up in the seed.

The genera differ in the fruit, whether fleshy or dry, in the ovary being one or two-celled, in the shape of the stigmas, and the hairiness of the filaments.

Of the other species commonly grown in gardens, or otherwise known:—

I. CARNEA, Jacq. is a garden shrub with somewhat leafless stems and large pale mauve flowers, which are usually very numerous at the beginning of the hot weather.

I. HEDERACEA, Jacq. has bright blue or purple flowers, and palmately three-lobed leaves.

I. BONA-NOX, L., the Moon-flower, has a corolla of a rather different shape having a narrow tube with large almost flat limb. It opens at night, and emits a strong scent, which attracts moths, for whose long tongues this tube appears to be an adaptation (p. 235).

I. QUÆMOCLIT, L. is a small annual of a few weeks' duration, with dark green, very much divided (pinnatisect) leaves. The corolla has a tube, an inch or so long, of a brilliant red colour, with expanded limb.

I. BILOBA, Forst., (I. PES-CAPRÆ, Roth.), is a creeper on sandy seashores. The leaves are two-lobed; the creeping stems and branches are usually covered by the drifting sand, but the leaf-stalks lengthen to keep the blades above it (p. 112). It is very common on sea beaches in the Tropics, where it grows with

certain other plants usually on the tops of little rises of the sand kept by it from being blown away.

I. PES TIGRIDIS, L. is another seashore plant with palmately lobed leaves (like a tiger's spoor).

FIG. 80. EVOLVULUS ALSINOIDES, L.

I. BATATAS, Lamk. is the Sweet-potato plant. The roots swell into tubers which contain sugar as well as starch, and are edible (p. 115).

EVOLVULUS ALSINOIDES, L. is a small herb with bright blue flowers, a quarter of an inch in diameter, which is very common amongst grass in sandy and

waste places. Its silvery white leaves are very variable in shape and size.

CONVOLVULUS PENTANTHUS, Jacq., which differs from the IPOMŒA in the stigmas being cylindrical, not globose, and has bright blue flowers an inch across, is very common in gardens.

BORAGINEÆ

Examples:—

TRICHODESMA INDICUM, Br., a herb, the stem and leaves hispid, or scabrid, with short stiff hairs on small swollen tubercles.

Leaves mostly opposite but some of the upper alternate, sessile, lanceolate, cordate or hastate at the base, entire, hispid. No stipules (fig. 81).

Flowers axillary, pedicels an inch or so long. Calyx deeply five-lobed, the lobes in fruit enlarged and produced outwards at the base. Corolla blue, about half an inch in diameter, with short tube and five spreading acuminate lobes. Stamens five, attached to the corolla tube and alternate with its lobes. Ovary of four cells with one ovule in each, style rising from between the four lobes of the ovary, stigma small. Fruit of four nutlets, each enclosing one seed in which the radicle points upwards, and rough along the inner angle where they were attached to the central axis.

HELIOTROPIUM INDICUM, L., (fig. 82), an annual herb, the stem and leaves rough with coarse hairs. Leaves alternate, exstipulate, petioled, ovate, slightly serrate, without stipules.

Flowers in a double row on one side of a long axis, which is coiled in a spiral at the end and may

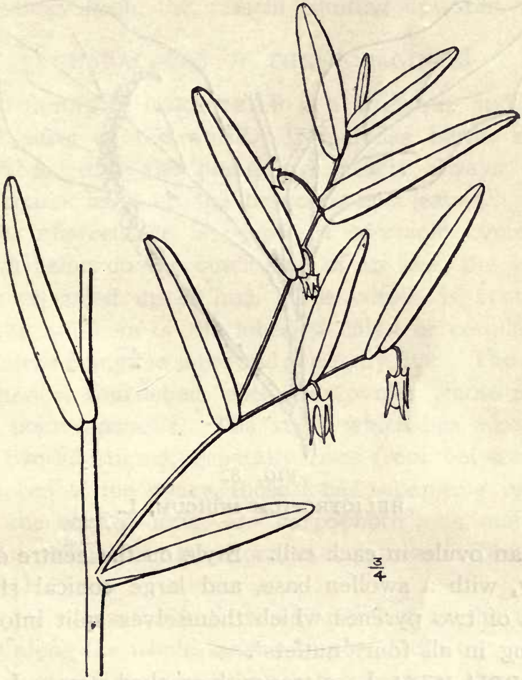

FIG. 81
TRICHODESMA INDICUM, Br.

look like a one-sided spike, but is really a cymose inflorescence of a sympodial type, each flower being the end of the axis—a typical scorpioid cyme (p. 195). Calyx of five lanceolate segments, corolla small, tubular below, spreading above with five lobes which are imbricate in bud, stamens five, with short filaments

attached to and included in the corolla tube, and alternating with its lobes. Ovary four-lobed, four-celled,

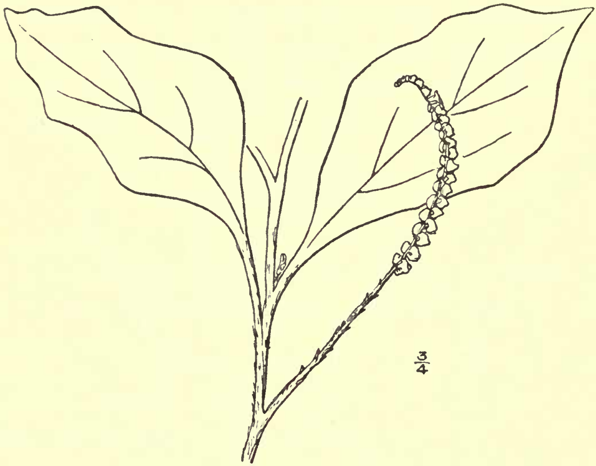

FIG. 82

HELIOTROPIUM INDICUM, L.

with an ovule in each cell. Style on the centre of the ovary, with a swollen base, and large conical stigma. Fruit of two pyrenes which themselves split into two, making in all four 'nutlets'.

CORDIA MYXA, L., a tree with crooked stem. Leaves large, alternate, petioled, ovate (but variable in shape), glabrous on the upper, scabrous on the lower surface, with no stipules.

Flowers staminate or bisexual, in cymose corymbs. Calyx irregular, corolla funnel-shaped with short lobes $\frac{1}{10}$ inch to $\frac{1}{8}$ inch. Stamens attached to corolla tube and alternate with its lobes, filaments hairy at the base, anthers shortly exerted. Ovary four-celled, four-ovuled;

style terminal, with two long linear stigmatic branches. Fruit a small drupe, containing one seed only with very sticky flesh, the radicle pointing upwards.

CHARACTERS OF THE BORAGINEÆ

The family of BORAGINEÆ is a large one, and found in all parts of the world. It includes herbs, shrubs and trees, and the plants are nearly always rough with coarse hairs on the branches and leaves.

The inflorescence is usually a scorpioid cyme, the flowers being on the outer side of an axis, the end of which is coiled up in bud. The corolla is sympetalous, the numbers of the lobes of calyx or corolla, and of stamens being the same and generally five. The ovary is superior, four-lobed, with four ovules whose micropyles point upwards. The style, which has a capitate or a two-fid stigma, generally rises from between the four lobes of the ovary, these lobes separating in fruit from the central axis, or 'carpophore', as one-sided nutlets. The fruit, therefore, is a typical 'schizocarp' (p. 241).

According as the nutlets are attached to the carpophore along the whole inner edge, or at the top, middle or bottom only, of each, so is the scar on the nutlet, and these differences are used to distinguish the genera.

* HELIOTROPIUM PERUVIANUM, L. is the well-known Heliotrope or Cherry-pie, grown so much in gardens on the hills. The flower is very similar to that of H. INDICUM, L., and is typical of the family. Another very typical plant is the true * Forget-me-not (MYOSOTIS PALUSTRIS, L.) which, with other species, is often cultivated in gardens.

* Comfrey (SYMPHYTUM), * Borage (BORAGO), * Viper's Bugloss (ECHIUM) and * Hound's tongue (CYNOGLOSSUM) are English plants belonging to this family.

An Indian species of the last, C. FURCATUM, Wall., is very common both on the plains and on the hills. It is not unlike the Forget-me-not, and takes its name from the long often bifurcating branches which bear the flowers. The nutlets are covered with hooked spines.

ACANTHACEÆ

Examples:—

RUELLIA PROSTRATA, Lamk., a herb with perennial rootstock and weak procumbent branches bent at the nodes. Leaves without stipules, opposite, petioled, ovate, entire, herbaceous, with a few hairs.

Flowers on short pedicles in the axils of leaves. Bracteoles two; sepals five, linear; corolla purple, about one inch long, tubular, narrow at the base, broader above, with five nearly equal lobes which are twisted in bud. Stamens four, didynamous, the anthers equal. Ovary superior, two-celled, with many ovules on axile placentas. Style terminal on the ovary, linear. Fruit a capsule, solid at the base, broader above; seeds flat on thick hard funicles. If the tip of the capsule be wetted when quite ripe, it bursts open suddenly, and by the pressure of the hard funicles the seeds are shot out. They then appear to be on parietal placentas, but in reality the septum dividing the ovary splits, one-half with its attached seeds going to each valve, which represents not a carpel, but two-half carpels. In water the outermost layer of the seed

becomes slimy, because covered with slimy hairs. Another species of RUELLIA (R. TUBEROSA, L.), found very commonly in and about gardens, is a West Indian plant. The leaves are larger than the above, softer and less hairy. The flowers are larger and of a pretty blue colour. The fruit is of the same type but larger.

ASYSTASIA COROMANDELIANA, Nees, a weak-stemmed shrub procumbent or straggling over hedges. Branches thin, grooved, leaves opposite, petioled, ovate, entire, herbaceous, pubescent, without stipules.

Flowers in one-sided racemes, the bracts opposite like the leaves, but with a flower in one only of each pair. Sepals five, narrow lanceolate, and pubescent. Corolla tubular, yellow, narrow below, wider above, with five nearly equal spreading lobes, which are imbricate in bud. Ovary superior, two-celled, with four ovules. Stamens four, attached to the tube of the corolla, style terminal on the ovary. Fruit a capsule, narrow and solid below, but containing above four seeds with thick hard stalks that spring out when ripe.

ADHATODA VASICA, Nees, a densely growing erect shrub. Leaves opposite, without stipules, petioled, elliptic, acute, entire and nearly glabrous, about eight inches long, with prominent pinnate venation.

Flowers in dense four-angled spikes; on axillary peduncles, with large bracts, which conceal them in bud. Bracteoles two, oblanceolate. Calyx deeply five-lobed. Corolla tubular below, above two lipped, the upper lip notched (or two-lobed) and curved forward, the lower spreading with three lobes. Lobes imbricate in bud, white, the lower lip often with pink

stripes across. Stamens two, erect under the upper lip, the anther cells pointed below, and one a little lower down on the filament than the other; the connective broad. Ovary superior, two-celled with four ovules; style terminal on the ovary, entire or with a short stigmatic branches. Fruit a capsule, two-celled with four seeds, the seeds small on stiff hard stalks.

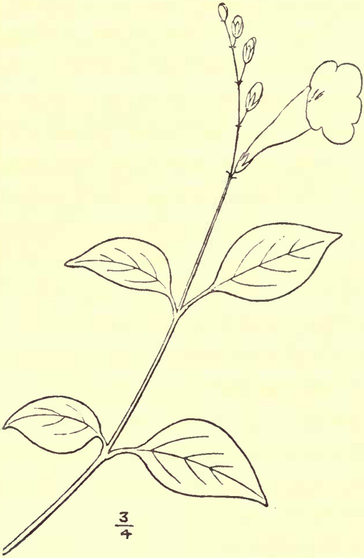

FIG. 83

ASYSTASIA COROMANDELIANA Nees.

Another important genus of this family is JUSTICIA, of which there are several species commonly found. The flowers are very like those of ADHATODA, but the anthers have conspicuous white tails, and are not pointed at the upper end.

J. BETONICA, L. is often cultivated. The flowers are in square spikes, the bracts stand in four ranks, are white with green veins, and are much larger than the sepals. The leaves are ovate, lanceolate.

J. GENDARUSSA, Linn. f. is also cultivated. The leaves are lanceolate, the bracts linear and shorter than the calyx.

J. PROCUMBENS, L. is a small very common herb with procumbent branches and small ovate leaves. The spikes are cylindrical, hairy, and with very narrow bracts.

J. DIFFUSA, Willd., also common in South India, has elliptic acuminate leaves and more slender spikes.

In all these the flower is of the same type, the corolla two-lipped, the upper lip with two, the lower with three lobes, imbricate (not twisted) in bud. The stamens are two, and the anthers have white tails. The corolla is generally white, marked with pink.

CHARACTERS OF THE ACANTHACEÆ

This family the ACANTHACEÆ is a large one, and almost entirely confined to the tropics. It consists mostly of weak-stemmed herbs and shrubs. The leaves are always opposite, without stipules, undivided and generally entire, and the branches are often swollen at the nodes. Bracts and bracteoles usually occur. The calyx is deeply divided into five sepals: the corolla is sympetalous, of five lobes, which in some are nearly equal, in others form two distinct lips; and the lobes may be convolute (twisted) or imbricate in bud. The stamens four or two (never five). The ovary is superior, of two cells; the fruit a loculi-cidal two valved capsule, with seeds on thick hard stalks, which in most cases shoot them out when the capsule opens. This last is the family's most characteristic feature. In some genera the capsule contains 4—6 seeds only, being empty and contracted at the bottom as in ASYSTASIA. Other common plants belonging to this family are:—

BARLERIA PRIONITES, L., a green-stemmed shrub with narrow leaves and a three-pronged spine at each

node, which represent an axillary branch that does not develop; there being another bud to become a branch if necessary. The flowers are in spikes like those of ADHATODA.

ANDROGRAPHIS PANICULATA, Nees, with weak square stems, and flowers in loose axillary racemes. Capsules oblong, not contracted below, with six or more seeds.

THUMBERGIA, twining shrubs, of which various species, especially T. GRANDIFLORA, Roxb. are cultivated in gardens on account of their large blue handsome flowers. The capsule is in this genus swollen below and has a narrow beak above, and the seeds are not on strong hard stalks; in which respects it differs from all others of this family.

*STROBILANTHES KUTHIANUS, T. Anders. is a well-known shrub growing in clusters in the open moors of the Nilgiri and Pulney Hills. It is a multiennial (p. 74) flowering when about twelve years and then dying. The leaves are elliptic, crenate, serrate, white beneath but with very conspicuous red veins. The flowers are of a pale purple or blue colour, the lobes of the inflated tubular corolla nearly equal, and twisted in bud like those of RUELLIA. The stamens four, or sometimes two only, and the ovary two-celled. The fruit is like that of RUELLIA.

LABIATEÆ

Examples:—

OCIMUM BASILICUM, L. the Sweet Basil, a very common plant and well known on account of its aromatic smell.

The stem is square in cross section, the leaves opposite, with long petioles and broad blades, ovate, acute, narrowed to the petiole, coarsely crenate, herbaceous, glabrous except for pubescence on the nerves of the upper side.

Flowers in groups of two or three, in terminal or axillary spikes. In each group of three the middle flower may be seen to open first, i.e. to be older than the two lateral. Each group is, therefore, a small cyme, and the inflorescence consists, really, of cymes arranged in decussate pairs on the axis of terminal and axillary spikes. Each cyme arises in the axil of a ovate-lanceolate bract, and there are two linear bracteoles subtending the other flowers. Pedicel about $\frac{1}{6}$ inch with glandular hairs. Calyx two-lipped, the upper lip round, obtuse, the lower with four sharp teeth. Corolla from $\frac{1}{3}$ to $\frac{1}{2}$ inch long, gamopetalous and two-lipped above, the upper lip erect with four divisions or teeth, the lower lip boat-shaped, bent downwards and entire. Stamens four, bent down and inside the lower lip, with small round or oval anthers, which open by one slit only (because the two halves become merged into one). Ovary with a yellow disc round it, four-lobed, the style rising from between the lobes and dividing at the top into the two-branched stigma. In fruit the calyx tube contains apparently four seeds, but seeds being always (in the plants we are dealing with in this book) formed in an ovary and not by themselves, these four bodies cannot be true seeds, but are the four lobes of the ovary which have come apart from each other and contain each one seed, though is impossible in the ripe state to

separate the seed from its enclosing part of the ovary. So that these four seeds are not seeds but parts of a schizocarp, they are usually called nutlets and of course they answer the function of seeds in every way (p. 241).

LEUCAS ASPERA, Spr., or on the hills take L. HELIANTHEMIFOLIA, Desf. The former plant is often used as a pot herb and is cultivated for that purpose in some districts. Stem much branched, four-angled, rough or scabrid with short stout hairs. Leaves opposite, decussate, linear or oblong, narrowed to the short petiole, generally crenate, and with pinnate venation.

Flowers arranged in dense clusters towards the ends of the branches, with three or four leaves coming out from the base and sometimes two from the top, and a number of linear bracts and bracteoles. The cluster can be divided easily into two parts, attached to opposite sides of the stem; each half again can be divided repeatedly into three parts, showing that it has a cymose arrangement: it is thus a **verticillaster** formed of two cymose inflorescences, larger and more condensed than in OCIMUM (p. 195). Calyx, tubular, curved, with, in L. ASPERA, L. a very oblique mouth opening forwards and, ten minute teeth at the ends of ten veins or ribs. Corolla white, monopetalous and two-lipped, the upper lip arched and very hairy on the outer surface, the lower large and spreading forwards, with three lobes, of which the middle one is the largest and slightly notched (emarginate). Stamens four standing up under the upper lip in two pairs **didynamous**, (the middle pair slightly longer than the outer).

Anthers small, the two halves of each at first separate **(divaricate).** Ovary deeply divided into four lobes, from between which rises the slender style. Fruit of four nutlets as in OCIMUM, not seeds.

CHARACTERS OF THE LABIATEÆ

These two plants illustrate the characteristics of the family LABIATEÆ. The stems are usually square in cross section, have always opposite leaves, monopetalous, more or less two-lipped (generally very much two-lipped) flowers, in cymose, usually dense, clusters (verticillasters) near the ends of the branches. There are four or two stamens, and the fruit always consists of four nutlets, which contain each one seed, united to the pericarp.

Most of the family have strongly scented leaves, the scent being due to a volatile oil in glands on the surface (not inside as in the MYRTACEÆ and RUTACEÆ).

Other common plants belonging to this family are:—

* MENTHA SATIVA, L. common Mint, which has dense masses of almost regular campanulate flowers with four lobes and four equal stamens, but is otherwise like LEUCAS or OCIMUM. Three other species M. VIRIDIS, L. the Spear-mint, M. PIPERITA, L. the Peppermint and M. AQUATICA, L. also occur in gardens.

* THYMUS SERPHYLLUM, L. the wild Thyme of England.

* MICROMERIA BIFLORA, Benth., a small plant with usually only two large pink flowers out at a time, exceedingly common on grassy hills of the Nilgiri and Pulney ranges, and generally known there as Thyme.

SALVIA SPLENDENS, Sell. in gardens. The calyx is red as well as the corolla.

Two other species, S. COCCINEA, V., and a white variety of it, and S. OFFICINALIS, L., the Sage, are also grown. The stamens of SALVIA are peculiar in that the filament is very short, and one-half only of the anther is developed and borne forwards on a long branch of the connective, the other branch with no proper anther lobe extending backwards in a straight line with the first (see p. 221).

LEONOTIS NEPETÆFOLIA, Br., a common weed by road-sides. Its gorgeous yellowish-red flowers, larger even than those of SALVIA SPLENDENS, aggregated in globuse clusters, make it a very handsome plant.

There are also several other species of LEUCAS, common in different parts, e.g. on the plains:—L. LINIFOLIA, Spr., a way side weed with narrow leaves, an very oblique mouth to the calyx, like L. ASPERA Spr.; L. ZEYLANICA, Br. and L. DIFFUSA, Benth. which differ from the former in the calyx being straight and even and in the whorl of flowers being terminal only; and on the hills, L. * HELIANTHEMIFOLIA, Desf., a small plant growing in tufts of about a foot high; L. * ROSMARINIFOLIA, Benth., a flat-topped bush with bluishgreen leaves and fruiting clusters on long stalks; L. * VESTITA, Benth., with brown, hairy upper lip; L. * LANCEÆFOLIA, Desf., and others. In the sholas we find, * SCUTELARIA VIOLACEÆ, Heyne, the Scull-cap, the calyx of which forms in fruit a curious sort of box with a flat back, and on the open moors * BRUNELLA VULGARIS, L. the Self-heal.

AMARANTACEÆ

Examples :—

CELOSIA CRISTATA, L., many varieties of which, with yellow, pink or red flowers, are grown under the name of Cock's-comb in Indian gardens.

It is an annual, with alternate, simple, exstipulate leaves (which vary in shape).

Flowers in short or long spikes, bracteate, and with two small, lanceolate, acute bracteoles. Perianth of five scarious, glistening, white (or coloured) sepals. No petals. Stamens five, opposite to the sepals; filaments united below into a cup, anthers two-celled. Ovary one-celled, with a central style and small capitate stigma. Capsule thin and scarious, opening by a circular slit so that the upper half comes off. Seeds many, on a central, basal, placenta; very smooth and shining, black, with a curved embryo.

CHARACTERS OF THE AMARANTACEÆ

The AMARANTACEÆ are herbs with exstipulate leaves, and may nearly always be recognized at once by the small regular flowers, in wild plants usually greenish-white in colour, in cultivated varieties red or yellow, sometimes sterile and in dense masses, but always scarious, glistening and hard.

There are no petals, the perianth consisting only of five scarious sepals. The stamens are five or fewer, and stand opposite to the perianth lobes (which therefore are sepals), and are often connected at the bottom by a membrane, or have intervening staminodes. The ovary is one-celled (but not one carpelled for the

style is central), with a basal and central placenta. The fruit is in most cases a utricle, i.e. thin walled; and circumciss, the whole upper half coming off. Seeds one or more, with curved embryo and generally shining black testa.

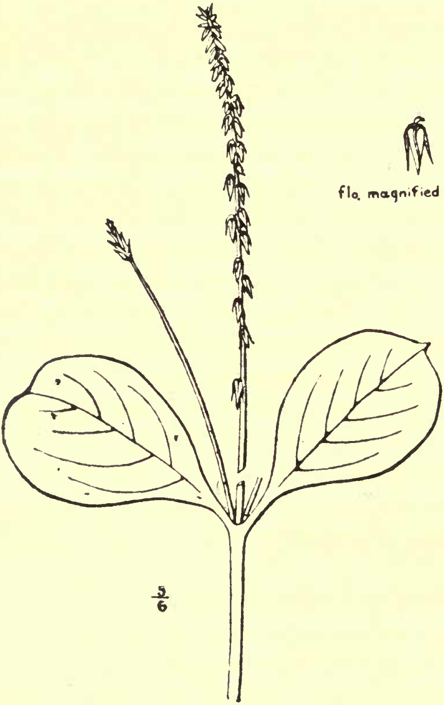

FIG. 84

ACHYRANTHES ASPERA, L.

The family is divided into two main groups according as the anthers are one or two-celled.

Other species are:—

ACHYRANTHES ASPERA, L., (fig. 84), very common one on the plains of India. The fruits are bent down and closely oppressed, and have five stiff pointed sepals surrounding them. Another species, * A. BIDENTATA, Bl., is common on the hills.

PUPALIA ATROPURPUREA, Moq. and P. LAPPACEA, Moq., fairly common over most of India, are peculiar

in that the flowers occur in clusters of three, the middle one only being fertile, while the sepals of the two others form strong hooked spines by which the whole cluster may fasten on the fur of animals, (p. 263).

EUPHORBIACEÆ

Examples:—

RICINUS COMMUNIS, L. the Castor-oil plant, an annual herb or shrub, in some varieties red in others green, and sometimes with a bluish-white (glaucous) powdery substance on the stems and petioles.

Leaves alternate, and covered completely in bud by the large stipules, which falling off leave a scar extending right round the stem. Petiole with large glands on either side at the base and near the blade. Blade peltate, orbicular, palmately lobed; the lobes serrate, membranous, glabrous.

Flowers in thyrsoid panicles, unisexual and **monœcious,** the upper flowers with stamens only, the lower with ovary only. Staminate flowers with three to five valvate sepals, no petals, but numerous stamens with branched filaments and distinct round anther cells; no ovary. Ovary flowers with calyx which falls off, no petals, no stamens, and a three-celled ovary with three styles; and in each cell one pendulous ovule attached at its top end to the inner angle. Fruit a capsule dividing into three parts, each splitting open and setting free its seed. Seed oblong with hard testa, symmetrically marked on the rounded side, and having a whitish soft caruncle covering the micropyle

at the upper end (see p. 268); raphe ventral, micropyle facing upwards and outwards. Embryo straight with two thin flat cotyledons, surrounded by oily endosperm.

CODIÆUM VARIEGATUM, Bl., the common Indian Croton, grown in all gardens of South Indian plains, for the almost infinite diversity of its foliage.

Flowers unisexual, monœcious, the staminate and ovary flowers being sometimes on the same, sometimes on separate racemes of the same plant. Staminate flower with five sepals imbricate in bud, five small fringed petals, inside and alternating with these last five round yellow glands, and on the convex thalamus many stamens with two-celled anthers (which in CODIÆUM becomes later on confluent at the top). Ovary flower with five small green imbricate sepals, no petals, a five-lobed yellow disc, and an ovary of three cells with three styles, with in each cell one ovule attached to the inner (axile) angle, near the top, and pendulous with ventral raphe; cells of the ovary splitting apart in fruit, as three one-celled cocci. Seed with a fleshy aril at the micropyle end, and a straight embryo imbedded in endosperm.

CHARACTERS OF THE EUPHORBIACEÆ

In its alternate simple leaves, its small inconspicuous flowers, their unisexual nature, and in the three-(two to four)-celled ovary containing pendulous seeds with ventral raphe, CODIÆUM is typical of the EUPHORBIACEÆ. The family is divided into two main groups, according to whether there are two, or only one ovule in each cell of the ovary.

And these groups are again sub-divided according to the presence or absence of petals, the æstivation of the calyx, the number of stamens, which are in some few and definite, in others many by branching (p. *220*); and the nature of the fruit, whether a drupe or, as in most cases, a capsule. In some genera the leaves are opposite or are compound, but these are differences of minor importance, and the members of this large family can nearly always be recognized without any difficulty by the characters given above as typical.

The genus EUPHORBIA, which gives the name to the family and is the only representative of it in England and Northern Europe, has very much reduced, and in appearance utterly different, flowers aggregated into small heads which themselves look like small simple flowers (see description of POINSETTIA), and is therefore not typical of the family.

Of the common and better known EUPHORBIACEÆ, mention may be made of:—

ACALYPHA MARGINATA, Spreng., a very common foliage plant in Indian gardens, the leaves being coloured red, or with a red margin. The flowers are in long pendulous axillary spikes, the staminate flowers very small, (six or seven of them in a cluster less than $\frac{1}{8}$ inch in diameter), with four valvate sepals and many stamens. The ovary flowers larger, each in the axil of a toothed bract, and consisting of a three-celled ovary with three much-branched styles, and at its base three or more minute sepals, but no petals.

A. INDICA, Bedd., a common weed. On the spike are ovary flowers at the base, staminate flowers

above, and at the top of a slender flowerless axis a single sterile ovary flower of a different type.

Another species, A. HISPIDA, Burm., has minute flowers massed in dense red pendulous spikes, of as much as a foot in length and $\frac{3}{4}$ inch in diameter.

The EUPHORBIACEÆ are a large family found all over the world but mostly in the tropics. Some are valuable economic plants, e.g. MANIHOT, from whose tuberous roots Tapioca or Cassava flour is obtained, and HEVEA, whose latex is the chief and best source of rubber (Para-rubber).

POINSETTIA PULCHERRINA, Graham, the Lobster flower, is a shrub grown very commonly in Indian gardens, on the plains and on the lower hills, for the gorgeous red leaves which grow just beneath the inspicuous flowers.

The leaves are alternate with minute stipules, simple, entire or lobed, and glabrous. At the ends of the branches are a number of ovoid green masses, the younger ones with perhaps three red styles, the older with a stalked three-lobed ovary, protruding from the middle. Each of these, called a **cyathium,** is enclosed in a green calyx-like involucre, which has a red fringed top, and on one side a large yellow gland often full of honey. If from a young cyathium, in the centre of which can be generally seen three red styles (though sometimes these are absent), the involucre be carefully removed, there will be found inside five, as it were columns, formed of numerous anther lobes tightly

packed together in pairs one above the other, and in the centre at the top, an ovary with three red styles. In an older cyathium some of the anthers protrude beyond the involucre and the stalk of each pair of lobes then appears as red in its upper, white in its lower half; the two separated by a very faint depressed line which in EUPHORBIA HETEROPHYLLA (a plant often grown in gardens and very like POINSETTIA but that the uppermost leaves are only half, not entirely red), is a little clearer so that the stalk appears as of two distinct parts, a lower and an upper. In some other species this spot is also marked by a cuplike ring of tissue. It will be seen too, without much difficulty, that the stalks of these anthers are arranged not exactly one behind another but in a zig-zag line, and that mixed with them are a number of filaments or hairs (without anthers). If we take an older cyathium, in the centre of which is a three-angled ovary with three styles, we shall find that the stalk is expanded as a roundish flat red disc on which the ovary itself rests, reminding one a little, though it is much more closely attached to the ovary, of the green calyx seen at the base of the orange fruit.

The structure of this complicated cyathium may now be easily explained. The central organ is an ovary flower in itself, the red disc just described being all there is of the much reduced calyx (perianth), and the stalk is its pedicel. Each stalked anther is also a flower in itself with one stamen only. The lower white part is the pedicel of the flower, the upper red part the filament of the stamen, and when

there is a ring of tissue at the junction of these two, it represents the perianth.

There remain to be explained only the hairy filaments which are intermixed with the stalked anthers. In young stages while the parts are still stiff enough to be readily distinguished, it may be seen that for the most part they go with the stalked anthers, one to each, so that they must be the bracteoles of the flowers; but some are sterile stalked-stamens, i.e. sterile flowers. The green involucre which surrounds the cyathium is made up, like that of the capitulum of the COMPOSITÆ, of bracts.

The zig-zag arrangement of the staminate flowers shows that they are arranged in the same way as in HELIOTROPIUM, i.e. in the form of a scorpioid cyme whose axis is very short and curves back from the centre of the cyathium towards the periphery, while the pedicels of the individual flowers are in proportion longer than with HELIOTROPIUM.

The cyathium then is a condensed inflorescence, very much more condensed than even the capitulum of the COMPOSITÆ. The latter may be regarded as simply a condensed umbel, in which there are no pedicels, or as a spike in which the peduncle is expanded laterally instead of upwards. But in EUPHORBIA and POINSETTIA there are; enclosed in the involucre, five distinct scorpioid cymes of staminate flowers, surrounding a single ovary flower, or, in all five or six separate inflorescences of very much reduced flowers.

Though this family is named after the genus EUPHORBIA, by far the greater have the simple flowers of RICINUS, CODIÆUM and ACALYPHIA. EUPHORBIA

and POINSETTIA are quite peculiar in their complicated inflorescence, and must not therefore be taken as types of the family. The genus EUPHORBIA is interesting in containing a number of species of a very zerophytic character with thick fleshy axis, stout thorns and no leaves; sometimes confounded for that reason with the Cactus but in reality quite distinct, for there are no cushions of barbed hairs. The plant has very sticky latex which contains an acrid substance that will raise blisters on the skin. Common species of this genus are:—

E. TIRUCALLI, L., a shrub or small tree, with cylindrical green branches the thickness of a lead-pencil, which is often to be seen round villages in the drier parts of South India and Ceylon though not really a native;

E. TORTILIS, Rot., a succulent with angular green twisted branches set with short stout paired thorns, whose position shows them to be modified stipules;

E. ANTIQUORUM, L., similar to it but larger, and

* E. ROTHIANA, Spr., the common 'Spurge' of the hills.

URTICACEÆ

Examples:—

ARTOCARPUS INTEGRIFOLIA, L. the Jak, a tall tree with thick branches and dense white sticky juice (often used as bird-lime).

Leaves alternate, petioled, obovate, cuspidate, entire, coraceous and glabrous. Stipules large, forming a complete hood over the next internode and leaving a prominent scar right round the branch.

Flowers very small, unisexual, monœcious, in separate, dense, globose or cylindrical, spikes borne on small short branches from the lower part of the stem. Spike of staminate flowers the size of one's thumb; perianth of two parts only; stamen one, filament thick, anther two-celled. Spike of ovary flowers more globular; perianth tubular with very small orifice; ovary straight, one-celled with one pendulous ovule. Fruit a large oblong or globular mass, a **multiple** fruit, formed of the thick fleshy receptacle covered by the numerous enlarged flowers, the perianths of which are leathery and form a romboid pattern on the surface, the ovary being also enlarged and fleshy. Seeds, when developed, kidney-shaped and rather large.

A. INCISA, L. the Bread-fruit tree of the Pacific islands, is occasionally cultivated in India. The leaf, as the name implies, is deeply incised (pinnatifid), and the stipules are very large, as much as six inches or more in length. The interior of the fruit is of the consistency of bread and is eaten roasted.

FICUS BENGALENSIS, L. the common Banyan, has like ARTOCARPUS, a thick white sticky latex, and stipules which form a hood over the bud, and falling off, leave a ring-like scar right round the branch. The small red berry-like fruit is also like that of ARTOCARPUS, a multiple fruit, composed of many small flowers, but differs in that they are inside not outside the receptacle, which is hollow and has a small hole at the further (distal) end, almost closed by a number of hair-like structures. These are considered to be sterile flowers. The staminate and ovary flowers are very minute; the former have, like those of

ARTOCARPUS, one (or two) stamens and four sepals; the latter are of the two kinds, some having a short the others a longer style, and contain but one ovule. It is not easy to make out these flowers completely, but the general structure of the receptacle and its flowers can be seen without any difficulty if a young fruit is cut open. Other common species of FICUS are:—

F. RELIGIOSA, L., the Peepul or Bo tree. The leaves have long acuminate points, and move with the slightest breeze because the petiole is flattened. In this respect the tree resembles the Aspen of Europe.

F. GLOMERATA, Roxb., the common Indian edible Fig. The edible Fig of Egypt and South Europe (the common Fig sold in a dry state) is the fruit of another species, F. CARICA, L.

F. HETEROPHYLLA, L. (F. SCANDENS, Roxb.) the Indian Ivy, a small creeping plant and root-climber, whose leaves lie closely oppressed to the tree or wall on which it is growing, or if borne on free branches are of a different shape.

ARTOCARPUS and FICUS are the examples of URTICACEÆ, which are perhaps commonest on the plains of India.

There are others with much the same sort of reduced flowers (for a flower which consists only of two sepals and one or two stamens, we must consider as reduced), but with these arranged in some other way, e.g. on a flat angular receptacle as in DORSTENIA.

But another large section of the family consist of plants which have more normal flowers, such as the Nettles (URTICA and LAPORTEA), and Nettle-like plants

(PILEA, PROCRIS, etc.), which are common enough on the hills in shady places.

In these the flowers are unisexual and small, and arranged in various ways. The staminate flowers have four sepals and standing opposite the sepals, four stamens bent down in bud, and when the sepals have opened, the stamens will at the slightest touch spring up straight and scatter the pollen as a tiny cloud of yellow dust.

This arrangement of the stamens opposite the perianth leaves and their ejection of the pollen by the sudden straightening of the filaments, are very characteristic of one large section of this family, which differs also from the FICUS and ARTOCARPUS section in having no latex.

AMARYLLIDEÆ

Examples:—

CRINUM ASIATICUM, L. This well-known plant is commonly grown in gardens for the sake of its beautiful large white flowers. It has no stem, the leaves springing from an underground bulb. The leaf has no separate stalk and blade, but consists of one large lamina, three to four feet long, and as many inches wide, along which run in addition to the mid rib and parallel with it, a number of veins, not branching as in most dicotyledonous leaves but lying side by side and connected only by small transverse veins.

Flowers borne in an irregular umbel on a thick leafless stalk (scape), enclosed at first by a thin

brownish coloured bract, the spathe, which as the flowers expand splits open along one side. Ovary inferior, three-celled. Perianth tubular below, above divided into six narrow white segments, three of which may be considered sepals and three petals. Stamens six on long filaments, three alternate with the sepals and three with the petals. Anthers long, attached to the filament lightly at the back (versatile), and opening in two long slits. Style single, with very small stigma; ovules numerous, placentation axile.

Careful observation will show that the cells of the ovary are opposite to the outer perianth lobes (sepals) and to three of the stamens, the other three being opposite to the petals. There are thus altogether five whorls or circles in the flower, two of the perianth (sepals and petals), two of stamens (an outer and an inner) and one of the cells (or carpels) of the ovary. Each whorl thus consists of three members which alternate always with those of the next whorl.

PANCRATIUM, also grown in Indian gardens, resembles CRINUM in almost every respect, having six perianth segments, six stamens, and a three-celled inferior ovary; but differs in the filaments being united by a thin white membrane, which forms a sort of cup, and (the common garden species) in its much narrower and shorter leaves.

EUCHARIS CANDIDA, Planch the Eucharis lily, is another well known garden plant. Its leaves rise from an underground bulb, the flowers are in an irregular umbel, enclosed at first in a spathe, on a stout scape. The filaments of the stamens are very broad and touch each other.

In this as in CRINUM and PANCRATIUM if we consider the six stamens as two whorls of three each, all the parts of the flower are in threes, in regularly alternating circles.

CHARACTERS OF THE AMARYLLIDEÆ

These three genera are good examples of the family AMARYLLIDEÆ, the characteristics of which are, the short tuberous or bulbous root-stock with except in some cases, no aerial stem, the parallel venation of the leaves, the inferior ovary, and the number three or six of all parts of the flower.

Other common plants :—

AGAVE AMERICANA, L. and A. VIVIPARA, L. are used for hedging railways and gardens; another species A. SISELANA is planted for the sake of the fibre which can be extracted from the leaves.

ZEPHYRANTHUS TUBISPATHA, Hacb. the Indian Crocus, a small plant whose scape is six or eight inches high, is common in gardens, and occasionally wild on the hills. It is a native of Peru from which it has been brought to India.

HIPPEASTRUM, different species and hybrids of which are sometimes grown in gardens (under the name of AMARYLLIS), belongs to this family, as also does the Narcissus and Daffodil.

LILIACEÆ

The family LILIACEÆ resembles the AMARYLLIDEÆ in that the parts of the flowers are in threes or sixes, but the ovary is superior not inferior.

It inhabits mostly colder climates, but one species, GLORIOSA SUPERBA, is common on the plains of South India (fig. 85).

Root-stock tuberous, stem above ground-climbing. Leaves alternate or with opposite, sheathing petioles, lanceolate or elliptic, entire, parallel-veined, acuminate and prolonged as a tendril.

Flowers on long axillary pedicels. Perianth of six linear segments coloured red and yellow, curled backwards (reflexed), and waved. Stamens six, filaments filiform; anthers linear, dorsifixed, versatile. Ovary three-celled, superior; style single.

FIG. 85

GLORIOSA SUPERBA, L.

The Lilies, Tulips, Hyacinth, Asparagus, autumn Crocus (not spring Crocus), Crown-imperial, Solomon's Seal, Onion and other bulbous plants familiar in English gardens and on hill stations belong to this family. To it also belong :—

SIMILAX, which is common on the hills. It is a climbing, often thorny, shrub with tendrils arising at the base of the leaves, and brilliantly coloured berries (see plate and p. 266).

ASPARAGUS, with wiry stems and linear green cladodes. The flat green organs of this plant which look like leaves are in reality modified branches, the leaves being reduced to minute brownish scales in the axils of which these modified branches arise.

DRACÆNA, varieties of which are grown as foliage plants on the plains. Some of the species grow into small trees and increase enormously in thickness—a very unusual thing in monocotyledons. One famous tree at Teneriffe (Spain) was seventy feet high and forty-five feet in girth and was supposed to be six thousand years old, when blown down forty years ago.

YUCCA, an Agave like plant, with large white bell-shaped flowers which smell strongly at night. It is a native of Mexico, and is grown in many gardens on the hills. In this too the stem increases in thickness.

CORDYLINE (fig. 86) is another aborescent genus grown in the Ootacamund and other gardens; but these are practically the only instances known of stem of monocotyledons growing in thickness (p. 79).

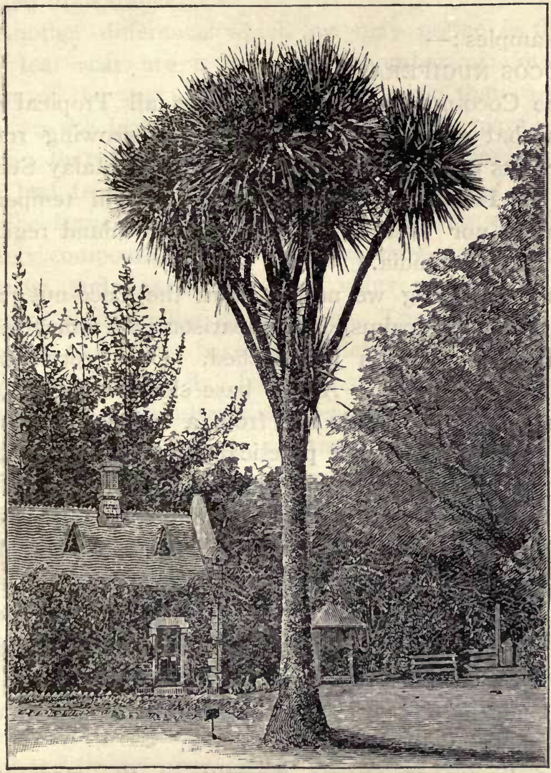

FIG. 86

CORDYLINE AUSTRALIS, Hk. f.

A tree belonging to the family LILIACEÆ.

This habit is very rare among the monocotyledons and the very peculiar appearance, when compared with ordinary trees, should be noted.

PALMEÆ (The Palms)

Examples:—

Cocos nucifera, L.

The Coco-nut palm is common in all Tropical districts that are not far from the sea, growing round the coasts of America, Africa, India, the Malay Straits and the Islands of the Pacific but not in temperate climates, nor even in the sub-tropical inland regions, e.g. northern India.

The first thing we notice about the Coco-nut palm (and indeed all palms) in comparison with other trees, is that the stem is unbranched. Only very rarely does a palm branch. At the base close to the ground, the stem is thickened, but from a height of two to four feet it remains of practically the same thickness right up to the top; in young and in old plants it is of about the same thickness. This means that unlike dicotyledonous trees, such as the Mango, a palm does not grow in thickness, but only in height.

At the base of the stem a number of roots grow out into the ground, each of about the thickness of a large pencil. All the roots of the Coco-nut are of this kind, there is no tap-root nor any branched system of roots as in dicotyledonous plants.

The leaves are borne directly on the stem, and since there are no axillary branches, when once they have fallen off no more appear on that part of the stem, so that one finds them only at the top, where they are formed, the youngest being nearest the apex, as in all other plants. They have large sheathing bases, and after they have fallen off, the leaf scars almost

encircle the stem and give to it its familiar and peculiar ringed appearance.

Another difference which we may notice is that in the leaf scar are a very large number of dots (the scars of the vascular bundles), far more than we ever find in the leaf scar of a dicotyledonous plant. This shows that a large number of vascular bundles enter the leaf from the stem.

The leaves of the Coco-nut are very large and pinnately compound. Each leaflet is very tough, long and narrow, and has a number of veins running along its length, with smaller cross veins. The midrib is much thicker, and at the base the leaflet appears to be folded downwards along it. In these respects the leaves of the Coco-nut are utterly different from those of ordinary trees; there is indeed, no real resemblance between them and ordinary pinnate leaves. (See p. 392).

Flowers unisexual and monœcious, the staminate and the ovary flowers, on the same panicle; branches of the panicle rather thick, with the younger flowers sunk slightly in them, and the whole enclosed when young inside two or more bracts—spathes—with other smaller bracts.

Staminate flowers unsymmetrical, with three small valvate sepals and three petals, both sepals and petals being very thick, leathery and shining, Stamens six, anthers linear, opening by two slits, and with sometimes an undeveloped ovary. Ovary flowers larger and with no stamens, only a three-celled ovary. Fruit, a hard nut surrounded by a fibrous substance and enclosed in a tough skin (epicarp).

The white substance which forms inside the nut as it ripens is the endosperm; this is hard and oily,

and in it is embedded the embryo. At the base of the nut are three round depressions one of which can be easily pierced.

Now the ovary has three cells, the ripe fruit only one. This means that always two of the cells cease to develop, but get squeezed to one side by the one cell which does grow. The three depressions at the base of the ripe nut correspond to the channels (vascular bundles) through which water and nourishment pass upwards into it, but those which lead to the two abortive cells become blocked with hard matter and so cannot be pierced as easily as the one belonging to the fertile cell. The nut, we see therefore, is part of the ovary and is not a seed; the seed is indistinguishable as such, having grown and amalgamated with the wall of the cell in which it lies.

Outside the nut, is a thick fibrous covering which is developed also from the ovary. When ripe this becomes very dry and contains spaces filled with air only, which make the whole fruit very light for its size, so that it floats easily in water. It may be for this reason that Coco-nut palms are so widely distributed and constantly found on sea-beaches of tropical countries and islands (p. 246).

BORASSUS FLABELLIFER, L.

The Palmyra or Toddy-palm occurs inland and in Central India, where the Coco-nut is not grown. Its dark-coloured stem, ringed with broad leaf-scars in which, as in the Coco-nut, may be seen the scars of the numerous vascular bundles that run from stem to leaf, ends in a crown of broad digitately folded leaves. This type of Palm leaf is known as the 'fan.'

The flowers are unisexual on separate plants (**diœcious**). The staminate inflorescence is a thick spadix covered with thick closely fitting scales or bracts from between which protrude the flowers. If a slice $\frac{1}{4}$ or $\frac{1}{2}$ inch thick be cut across from this spike, the flowers will be seen to protrude from little hollows between the bracts. In each hollow is a small inflorescence of flowers, arranged in zig-zag line, right and left, the oldest at the top or outside end, the youngest at the bottom and inside end, while beyond the oldest flowers are a number of scales. The lower, younger flowers are curved, and the whole is unmistakably a small scorpioid cyme, the main axis of which is very short and runs radially in the spadix. Each flower as it is ready to open, protrudes from between the bracts on the spadix. It has three concave, cuneate sepals, a tubular corolla with three obovate lobes, six stamens and in the centre three bristles which take the place of the undeveloped ovary. When a flower has withered the axis of the cyme lengthens, pushing it upwards and bringing into its place the next flower, which opens and is in turn pushed aside for the next. In this way there is a constant succession of flowers appearing on the surface of the spike.

The ovary flowers are much larger, occurring singly on the axis of their spadix. Perianth fleshy, sepals and petals three each, staminodes six or nine, ovary three celled, with three stigmas. Fruit a drupe of one or more cells.

CHARACTERS OF THE PALMEÆ

The Palms are typically straight, single stemmed plants, with a crown of leaves at the top. In a few there is no stem, e.g. NIPA FRUTICANS, Wurmb. which is common on the shores of many Eastern tropical countries. Of others, e.g. CALAMUS, the stem is very long and slender, climbing through and above the trees of a forest by means of thorns (p. 108); these stems are cut up and known familiarly as canes and from them are manufactured such things as Rattan-cane, the split-cane-matting of Indian houses, cane-bottoms for chairs, etc.

The Palm stem usually bulges a little at the level of the ground and tapers sharply below ground. There is no tap-root, all the roots arising from the base of the stem.

The leaf is very large and clasps the stem by a large sheathing base, which often remains on the stem with an untidy fibrous appearance for sometime after the rest of the leaf has fallen.

The leaves are pinnate (**feather** type) or palmately folded and cut (**fan** type). In some the folding of the leaflets or parts is like this Λ Λ Λ Λ in others like this V V V V. (This formation distinguishes the leaf of the Coco-nut from that of the Date).

The young leaf stands erect, and before it unfolds a thin strip of tissue may usually be seen covering the edges or tips of the leaflets. This is very clear in the young Date or OREODOXA, and is due to the fact that the leaflets are not out-growths of the midrib, as in dicotyledons, but formed by a splitting of the blade as it grows, the splits extending from the midrib not quite to the edge and leaving this strip.

The inflorescence is a branched spadix, in some terminal in others lateral, the flowers usually quite regular, their parts in threes—three leathery sepals, three petals, six stamens and a three-celled ovary; but in practically all cases the fruit contains but one cell, the other two being pushed to one side and not developing further, and encloses one seed. It may be a one-seeded berry as in the common Date (pericarp fleshy) and testa thin (p. 254) and Betel-nut (pericarp fibrous), or a drupe as in the Coco-nut and Palmyra (pericarp fibrous, endocarp stony). On germination the short radicle emerges first and is pushed down into the ground by the hollow stalk of the cotyledon which encloses the stem bud. The endosperm is hard (horny) and in many contains also oil. The digestion of this hard endosperm by the enlarged tip of the cotyledon may be very easily seen, if a germinating Date seed, Palmyra or Coco-nut is cut open, by the change in the colour and hardness produced (fig. 13, p. 59 & p. 60).

Palms are among the most useful of all plants. Their leaves are used in the tropics for a variety of purpose—roofs and umbrellas, books, mats, etc. From the base of the leaf is obtained a strong brown fibre used for making coarse brushes, and a thinner fibre from the fruit wall. The dried kernel (endocarp) of the Coconut is an important article of commerce being shipped to Europe, as 'copra,' for the oil it contains, and the hard inner wall of the fruit of another palm is used for making buttons. A sugary liquid which ferments is got from many palms such as the Palmyra, and Sago (almost pure starch) from the pith of some others.

AROIDEÆ

Example:—

CALADIUM BICOLOR, Ait. the common Caladium of our gardens, cultivated on account of its varied foliage. Leaves direct from the tuberous root-stock, simple petioled, sagitate or hastate, entire, net-veined.

Flowers minute, unisexual, and without perianth **(naked)**, crowded on fleshy spadix enclosed at first in large white spathe. Lower third of the spadix of ovary flowers only, each consisting of a two or three-celled ovary, with axile placentation, and topped by a minute stigma; fruit of each flower a berry, with oblong seeds containing straight embryos. Upper two-thirds of the spadix with closely fitting peltate structures, consisting of the stamens of a flower fused together, their anthers dependant below without perianth.

CHARACTERS OF THE AROIDEÆ

The AROIDEÆ vary a good deal in their vegetative character. Some are small others large, some have a tubeous root-stock or rhizome, some are climbing plants, others again are marsh plants, many have latex. The leaves are alternate, generally with distinct petiole and blade, and in some with net-venation. They are at once distinguished from all other families by the flowers being massed together on the fleshy axis of a spadix, enclosed at least at first in a spathe. The perianth consists of two to four scales or may be absent altogether. The stamens number two to six, the ovary is one to three-celled with small stigma.

The whole flower is very small, complete or more commonly, unisexual, monœcious, the two sorts being often separated on different parts of the spadix, or on different spadices, and in some cases there are in part of the spadix structures which must be regarded as sterile flowers.

Other common plants of the AROIDEÆ:—

COLOCASIA ANTIQUORUM, Schott is grown for the sake of its large tuberous (corn-like) root-stock.

ALOCASSIA MACRORHIZA, Schott has large leaves often variegated with pale green and white.

POTHOS with entire leaves and grooved petiole, PHILODENDRON, with pinnatifid leaves and round petioles, and MONSTERA with leaves both pinnatifid and perforated with large oblong holes, and winged petioles, are three root-climbers very common on trees in Indian gardens.

ANTHURIUM has scarlet or white spathes. The flowers are all alike, with both stamens and ovary, and a perianth of scales.

On the hills the best known example of this family is the common white 'Arum' or Calla-lily * RICHARDIA AFRICANA, K. (or CALLA ŒTHIOPICA, L.), (it is, of course, not a Lily at all). The flowers are all naked, as in CALADIUM; in the upper part of the spadix each consists of two or three stamens only, in the lower of an ovary with three staminodes.

ARISÆMA LESCHENAULTII, Bl. is a common wild plant, well known for its palmate leaves and brown spathe with nodding top. The plant is unisexual (or the flowers diœcious), the spadix containing either staminate or ovary flowers. The top of the spadix is sterile

and has no flowers, below are the staminate flowers consisting of two or more stamens, or the ovary flowers of one-celled ovaries; neither have any perianth.

MUSEÆ

Musa sapientum, L. the Plantain and Banana.

This plant is a herb, larger than many shrubs and even some small trees, but still a herb, for there is no woody stem. There is indeed no true stem at all above the ground, for what appears to be such is only the bases of the leaves tightly rolled round each other. There is a short slightly swollen root-stock, which buds out at the sides, and the usual method of propagating is by planting these offshoots. The leaves are very large, quite the largest of any plants except palms, and have large sheathing bases (referred to above as forming the apparent stem) and broad blades which in bud are rolled up from one side. The blade is traversed by a stout midrib from which numerous slender veins run straight to the edge. The most casual observation will show that in this respect the leaves of the plantain are very different from those of the dicotyledons flowering plants, such as we studied earlier on (see also under Palms, p. 392). There is no marginal vein running round just inside the edge as in many plants, e.g. the Peepul, and one effect of this is that the leaf is very readily torn by the wind. The surface of the leaf is very smooth and shiny. There are no hairs in it, neither above nor below.

Flowers in a double row, in the axils of the large bracts; those of the lower bracts with ovaries only,

those of the uppermost with stamens only, the middle ones hermaphrodite. Perianth a five-toothed tube, slit down on one side, with another petal inside quite detached from it. We may regard this five-toothed perianth as being composed of the union of five sepals or petals, which with the single petal inside make up six. Enclosed in the free petal, five stamens, corresponding to the five teeth of the perianth tube, with nothing opposite to the free petal; or in ovary flowers a three-celled ovary and a slender style the base of which is thickened; stigma six-lobed.

There are many ovules in the ovary, but in the common plantain these do not develop into seeds. The wall of the ovary itself becomes very thick and its inner part consists, when ripe, almost entirely of thin-walled tissue containing a good deal of water with starch and sugar, and its outer part forms the skin of the fruit. The fruit is in fact a berry, and in wild species fertile seeds are produced as in ordinary berries.

We see that the flowers may be considered or made up on the usual monocotyledonous plan of five whorls of three members each, just like the AMARYLLIDEÆ and the LILIACÆ, but complicated by the union of the three sepals and the two anterior petals into one tube, with the third, the posterior petal, free, and by the absence of one stamen, the one which should stand opposite this free petal and would therefore belong to the outer whorl of stamens.

The Plantain, MUSA, is by far the most important member of its family and the only one always available. Two others HELICONIA and STRELITZIA are often grown in large gardens, and so is also the

well-known Traveller's-palm, RAVENALA MADAGASCARIENSIS, Soun. It has a tall cylindrical stem, like that of a palm, and very large Plantain-like leaves spreading widely to right and left in two ranks, which give it an unique appearance. Rain water runs off the blades and collects between the leaf bases, and has been used when none other could be got, whence the vulgar name 'Traveller's-palm'.

CANNEÆ

Closely allied to the MUSEÆ is another small family, represented by the universally cultivated CANNA.

The flowers are arranged in pairs at intervals of an inch or more along the angular axis of a spike, and one of the pair comes out before the other.

The ovary is inferior, the sepals and petals being above it. At the base of each pair there are three bracts, one, the largest clasping the base of the older flower but subtending also the younger one to a small extent, the other two clasping the ovary of the younger flower. The explanation of this is that each pair constitutes a small two-flowered cyme, the largest bract being the bract of the first formed flower, the second bract the bracteole of this flower (and the bract of the younger) and the third (smallest) bract the bracteole of the younger flower.

Above the ovary are three dull coloured sepals, which persist on the flowers when the rest fall off. Then follow alternating with the sepals, three larger coloured, but when compared with the rest of the flower inconspicuous, petals, and above these the four

or five gorgeous petal-like structures which are the beauty of the Canna flower. In the centre rises a narrow flat rather firm structure; this is the style. Of the petal-like structures, the innermost (the one next to the style) has half way down its edge a one-celled anther; there can be no doubt, therefore, that it is a stamen, one-half only of the anther of which is developed normally, the rest being completely changed into a large flat expansion. The other petal-like structures are stamens of which the whole anther is changed into flat expansions, i.e. staminodes.

Reasoning from the analogy of ordinary monocotyledonous flowers in which there are two whorls of three stamens each, the innermost, half fertile stamen must, of course, belong to the inner whorl. Of the staminodes the innermost is usually spotted or otherwise different from the others, and this must, from its position, be another of the inner whorl of stamens. The other staminodes are by some botanists regarded as pieces of the third stamen of the inner whorl (on the supposition that the outer whorl is altogether absent), by others as this third stamen and two of the outer whorl, the third of the outer whorl being regarded as generally absent.

CANNA stands by itself, just as MUSA does, as by far the most important member of its small family.

ZINGIBAREÆ

ZINGIBER OFFICCINALE, Rose the Ginger-plant, HEDYCHIUM CORONARIUM, Koen. the wild ginger, and ELETTARIA CARDOMOMUM, Maton the cultivated

Cardamom, so commonly grown in the tropics, belong to another closely allied family, the ZINGIBAREÆ, and differ from Canna mainly in having a complete two-lobed anther between the lobes of which lies the style, and, at the base of the leaf-blade, a little flap of tissue, the 'ligule'. CISTUS and ALPINIA, grown sometimes in gardens, also belong to this family.

MARANTEÆ

MARANTA, the Arrow-root plant, belongs to yet another closely allied family which like Canna has a half stamen only, but differs in having a swollen joint (pulvinus) between the leaf-blade and its stalk, and in only one of the three cells of the ovary developing.

These four families the MUSEÆ, CANNEÆ, ZINGIBAREÆ, and MARANTEÆ, are sometimes placed together in one large family, the SCITAMINEÆ, in much the same way as the PAPILIONACEÆ, CAESALPINEÆ and MIMOSEÆ are in one family, the LEGUMINOSEÆ.

ORCHIDEÆ (The orchids)

Examples :—

VANDA ROXBURGHII, Br. grows on trees, being attached to the bark by roots, and has a number of narrow oblong leaves, notched at the top, thick, entire, and arranged in two ranks (distichous). There are in addition white cylindrical roots of another pattern, which hang down freely and are of about the thickness of an ordinary lead pencil. These are clearly roots, for they bear no leaves and come out of the

stem, as it were, through a slit in the cortex. Their white colour is due to a very porous outer layer which will absorb water, just as blotting paper does,

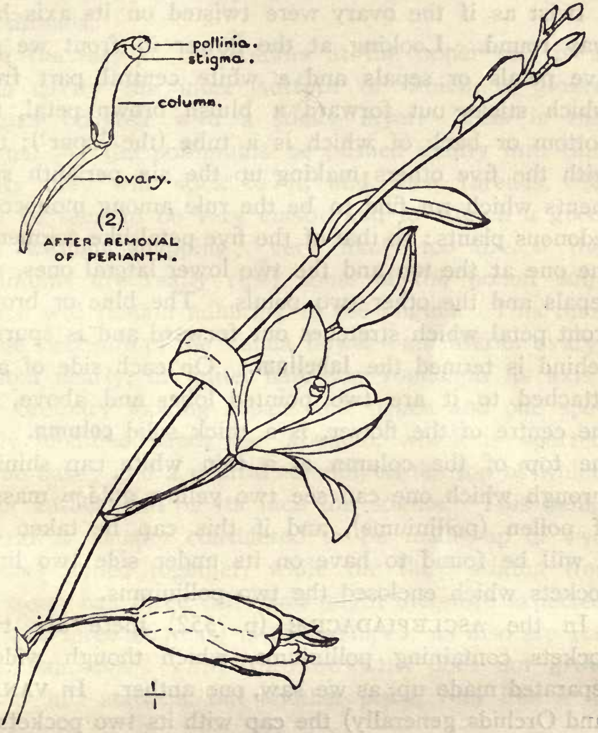

FIG. 87. An Orchid of the VANDA group
The labellum has been removed from the open flower

because of its porosity, and which when wetted allows the green colour beneath to appear through (see p. 129). The inflorescence is a loose raceme arising from the axil of a leaf. The flower appears to have

a white stalk, but this if cut across is seen to be really a long inferior ovary with three cells. It is deeply ribbed on the outside and the ribs show a twist as if the ovary were twisted on its axis half way round. Looking at the flower in front we see five petals or sepals and a white central part from which sticks out forward a bluish brown petal, the bottom or back of which is a tube (the 'spur'); this with the five others making up the six perianth segments which we find to be the rule among monocotyledonous plants: so that of the five petal-like segments, the one at the top and the two lower lateral ones, are sepals and the other two petals. The blue or brown front petal which stretches out forward and is spurred behind is termed the **labellum.** On each side of and attached to it are two pointed lobes and above, on the centre of the flower, is a thick solid **column.** At the top of the column is a thin white cap shining through which one can see two yellow golden masses of pollen (polliniums), and if this cap be taken off it will be found to have on its under side two little pockets which enclosed the two polliniums.

In the ASCLEPIADACEÆ (p. 352) there are two pockets containing polliniums, which though widely separated made up, as we saw, one anther. In VANDA (and Orchids generally) the cap with its two pockets is part of one much modified anther. From the front, basal end, of each pollinium extends a thin white thread which is connected to a comparatively broad strap attached to the front edge of the column. If a needle or pencil be pushed up gently against the flap at the top of the face of the column, the latter, being sticky,

will attach itself to the pencil and come off the column, and the strap will be seen above and behind it with the two polliniums connected to it by the threads.

In the face of the column at the upper end is a large cavity the inner surface of which is glossy because covered with a sticky layer. This is the stigma. If the polliniums be pushed gently into this cavity they will stick to it, and their threads will then be seen to be very elastic and to stretch a good deal without snapping; very likely too (i.e. if the polliniums are really ripe) some of the pollen substance will remain adhering to the stigma. This then is the structure of the Vanda flower—an inferior ovary, twisted nearly, or quite, half way round on its axis; five ordinary looking sepals and petals and one specially modified petal, the labellum, which is spurred at the base; and a central column, on the top of which is an anther, and on its face the stigma. This being central is usually considered to be made up of two stigmas joined together, while the third stigma (for the ovary has three cells and might therefore expected to have three stigmas) is undeveloped, as also are the other stamens. VANDA ROXBURGHII does not grow in our hill stations, but another plant, very like it in flower,

* ÆERIDES MACULOSUM, Lindl. is common on rocks and may be taken as the type instead. It is often brought round for sale, for the pink flowers and agreeable scent make the plant a general favourite, but as was said in chapter xii, every species has its own habitat to which it is adapted. It is absurd to expect

cold-climate plants, such as the hill-orchids and lilies, to grow on the plains.

HABENARIA, the white or purple ground Orchid of the Nilgiri and Pulney hills. There are several species differing from each other chiefly in the shape of the lip and in the position of the sepals and length of spur, but as regards the important characters of the flowers, so much alike that almost any may be taken and examined with the description given below.

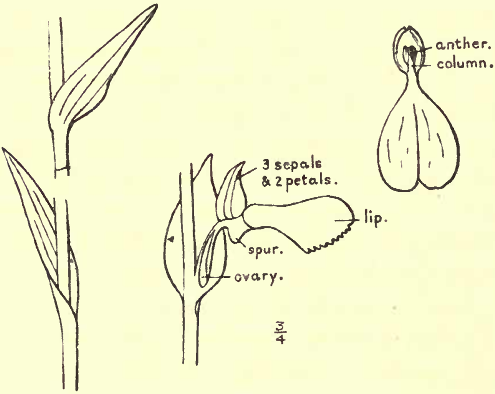

FIG. 88

HABENARIA GALEANDRA, Benth.

The plant has a tuber a few inches below the ground, from which rises a green herbaceous stem six inches or more in height. The leaves are alternate and clasp the stem by their lower parts, and are traversed by three or more parallel or arching unbranched veins of a typically basal, and monocotyledonous, character. There is no petiole, no pulvinus, the sheathing base and the spreading blade merging

into one another. The stem terminates in a spike of flowers each in the axil of a conspicuous bract.

Under the arching sepals and petals, just behind the opening of the hollow spur, will be seen a very short solid column flanked on either side by two pouches broad above and narrow below, which open in front by a slit and in some species curve forwards at the bottom but are generally straight. If a thick bristle or fine pencil point be pushed gently into the mouth of a newly-opened flower and be made to touch the bottom of the pouch, there will probably be found on it when withdrawn a small club-shaped body with a very sticky disc at the base, by which it is stuck to the pencil point, and ending above in the yellow mass of pollen—a pollinium—which filled the upper broader end of the pouch. The two pouches together form one stamen, the only one in the flower. On the front face of the column, just above the mouth of the spur and between the two anther lobes, may be seen the stigma in a slight cavity. This is sticky and if touched by a pollinium adheres to it so firmly that some of the pollen will be left on it.

We see, therefore, that the flower is on the same general lines as that of VANDA or ÆRIDES, the column being composed of a style and a stamen united into one body, but that here the two halves of the anther diverge so as to lie on either side with the stigma between them.

STRUCTURE OF THE ORCHID FLOWER

Now the typical flower of a monocotyledon, such as one of the AMARYLLIDACEÆ or LILIACEÆ, has three

sepals, three petals, six stamens in two circles of three each, and a three-celled ovary with three styles, or a single style and three stigmatic points; all the circles alternating with each other, so that the stigmas are opposite the sepals and alternate with the petals.

In the Orchid, therefore, while the three sepals, the three petals and the three-celled ovary are fully developed, only one of the stamens is; and the solitary stigma must, since it faces the labellum, really be the two front stigmas united into one. Some or all of the remaining stamens may perhaps be considered as making up part of the column, with the undeveloped style as its central axis and its stigma as the rostellum. The flower is usually upside-down for the labellum, being the odd petal, should point upwards but is brought to the lower side by the twisting of the ovary. A similar twisting, though more difficult to make out, occurs in the Balsams (IMPATIENS).

The differences between Orchid flowers are mainly in the exact position of the anther-lobes, their attachment, and the attachment of the polliniums to the removable part of the column, technically known as the **rostellum.** In the VANDA group the anther falls off but the polliniums are attached by a strap to the rostellum; in the DENDROBIUM group the anther is helmet-shaped and remains attached to a narrow thread to the column (fig. 89); and in HABENARIA, and Orchids like it, the anther lobes are separated and attached firmly to the sides of the column. There is another group, the Slipper-Orchids, CYPRIPEDIUM, in which the structure is quite different, the flower having

two distinct anthers which contain separate sticky grains of pollen, not polliniums, and the stigma being

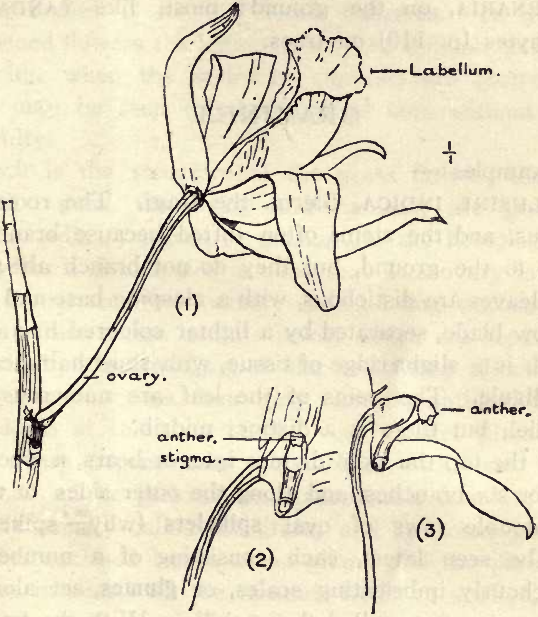

FIG. 89. CŒLOGYNE
An Orchid of the DENDROBIUM group.

single, not of two fused together. But in by far the greater number of Orchids, all the ordinary ones, the flower is very much as in DENDROBIUM, VANDA or HABENARIA. It is a very large family numbering over six thousand species, all perennial herbs with tubers or thick rhizomes. Many have most beautiful flowers, and are specially prized because of their rarity and the length of time they remain fresh.

Most Orchids belong to the tropical regions, but they occur in all parts of the world: some, like HABENARIA, on the ground; most, like VANDA, as epiphytes (p. 110) on trees.

GRAMINEÆ

Examples:—

ELUSINE INDICA, Gærtn. the Ragi. The roots are fibrous, and the stems often tufted because branching close to the ground, but they do not branch above it. The leaves are distichous, with a clasping base and long narrow blade, separated by a lighter coloured line along which is a slight ridge of tissue, with short hairs, called the **ligule.** The veins of the leaf are numerous and parallel, but there is a distinct midrib.

At the top the stem divides into, or bears, a whorl of five or six branches, and along the outer sides of these are double rows of oval **spikelets** (why 'spikelets' will be seen later), each consisting of a number of distichously imbricating scales, or **glumes,** set along a short axis often called the rachilla. With the fingers, or a pair of forceps, the spikelet may be pulled apart between the glumes, except the two lowest, the rachilla being jointed at each one. The glumes are boat-shaped with strong green backs (keels) and scarious sides, the two lowest (fig. 90 C 1 and 2) are empty, but in the axil of each of the others is a thin scarious scale, the **palea,** with two green veins along which it is folded towards the glume. Between the glume and its palea are the organs of the flower: in the middle an ovary with two styles; round it three

stamens, two on the palea side one on the glume side; and in front of these, next the glume, two soft white bodies (*l* in D) called **lodicules.** In young unopened flowers the lodicules may be difficult to make out, but when the styles or stamens are protruding they may be seen through a good lens without any difficulty.

Such is the structure of the grass flower; the essential organs, the ovary and stamens, are present, but no ordinary sepals or petals, and the homology of the palea and lodicules is obscure. The ovary is the first to mature, the feathery styles being pushed out between the glume and its palea, which are separated a little by the swelling of the lodicules; afterwards the stamens emerge, their long versatile anthers dangling down at the ends of the very slender filaments. The ovary ripens into an achene, with one seed enclosed in the pericarp and inseparable from it; this fruit is usually called the **grain,** and in some genera remains enclosed between the glume and the palea.

Now in nearly all the families we have studied, the flower is the unit of the inflorescence, being repeated over and over again to form it. In the COMPOSITÆ we get something a little more complicated, for we may have corymbs or spikes of flower heads; and in the genus EUPHORBIA this is still more the case, the cyathium being the indivisible unit. In the grasses the flower is again not the unit, for several go to make up, with two empty glumes, a little independent spike, which is repeated over and over again. Hence the importance of the conception of the spikelet, and its name. The inflorescence, i.e. the arrangement of

the spikelets, varies considerably, it may be a close spike, a spike of spikes, an umbel of one-sided spikes as in CHLORIS (B in fig. 90), or an open panicle as in ERAGROSTIS (A).

In many cases the glumes or some of them are awned, i.e. prolonged into hairs as in CHLORIS, in which also the upper two glumes are sterile (E. in fig. 90).

PANICUM

Numerous species of this genus are cultivated under the names millet, guinea-grass, etc.

The spikelets are in open panicles, or close spikes of spikes, and consists of two empty glumes (F 1 and 2), and only one or two flowering glumes. In the axil on the lower one (No. 3) are three stamens, but no ovary, in that of the second (No. 4) a complete grass flower. The whole spikelet is jointed to its pedicel

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EXPLANATION OF FIG. 90

A. Panicle of ERAGROSTIS TENELLA, Rœm and Sch.

B. Umbelled spikes of CHLORIS BARBATA, Sw.

C. Spikelet of ELEUSINE INDICA, Gærtn.; glumes numbered 1 to 7. The styles are out from the upper flowers before the stamens.

D. One flower of C.
r,r edges of the infolded palea.
o ovary with two feathery styles.
l,l lodicules.

E. Spikelet of B (CHLORIS) flowering glumes awned, No. 3 fertile, Nos. 4 and 5 empty.

F. Spikelet of the 'Guinea-grass', PANICUM, Glume No. 3 with stamens only. No. 4 (the topmost) alone fertile. Palea of this transversely ribbed.

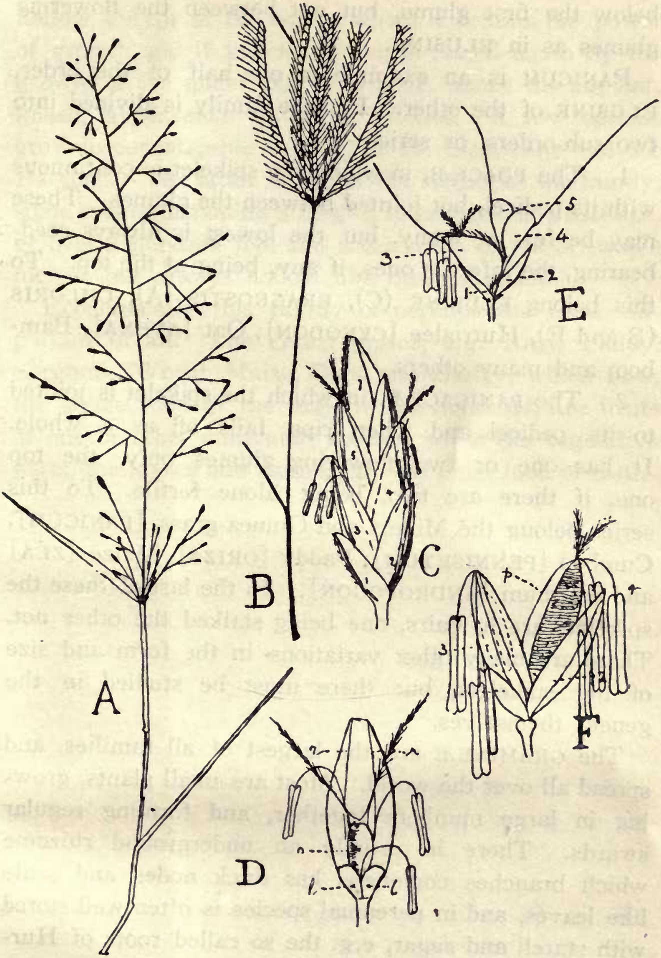

FIG. 90

GRASS SPIKELETS AND THEIR PARTS

below the first glume, but not between the flowering glumes as in ELUSINE.

PANICUM is an example of one half of the order, ELUSINE of the other. For the family is divided into two sub-orders, or series:—

1. The POACEÆ, in which the spikelet is continuous with its pedicel, but jointed between the glumes. These may be few or many, but the lowest is always seed-bearing, the infertile ones, if any, being at the top. To this belong ELUSINE (C), ERAGROSTIS (A), CHLORIS (B and E), Hurrialee [CYNODON], Oat [AVENA], Bamboo, and many others.

2. The PANICACEÆ, in which the spikelet is jointed to its pedicel and when ripe falls off as a whole. It has one or two flowering glumes only, the top one, if there are two, being alone fertile. To this series belong the Millets and Guinea-grass [PANICUM], Cumboo [PENNISETUM], Paddy [ORIZA], Maize [ZEA] and Sorghum [ANDROPOGON]. In the last of these the spikelets are in pairs, one being stalked the other not. There are many other variations in the form and size of the spikelets, but there must be studied in the genera themselves.

The GRAMINEÆ are the largest of all families, and spread all over the world. Most are small plants, growing in large numbers together, and forming regular swards. There is usually an underground rhizome which branches copiously, has thick nodes and scale like leaves, and in perennial species is often well stored with starch and sugar, e.g. the so called roots of Hurrialee (see pp. 116 and 119); above ground the stems seldom branch below the flowering region. The stem is

hollow, except at the nodes, where it retains the power of growth and if knocked down is raised again by the growth of the under side of a node, hence the angular, kneed, appearance of many grasses. A few species grow to considerable heights, as the Sugarcane and the Bamboo. The latter is by far the largest of the family, some species attaining a height, in favourable situations, of over a hundred feet and a thickness of ten or twelve inches, but always hollow like other grasses.

Economically this family is perhaps the most important of all. The cereal grains, e.g. Ragi, Paddy, Sorghum, Wheat, Maize, Oats, and Barley, which form the staple food of the majority of mankind, are fruits of one or other cultivated species, while the vegetative parts, the leaves and haulms, are the chief food of cattle.

REVIEW AND CONCLUSION

SYSTEMATIC

When discussing the nomenclature of plants in chapter xii, we saw that species could be grouped into genera by characters which are less likely to have been modified in the course of ages to suit the special conditions of the plant's life, than are the leaves and general habit. We have now learnt that genera may also be grouped into families, or NATURAL ORDERS as they are also called, the members of a family being alike not only in the general arrangement of the leaves (opposite or alternate, decussate, bifarious, etc.), and in the number and arrangement of the parts of the flower, which are the more definite characteristics, but also in such peculiarities as interpetiolar stipules (RUBIACEÆ), translucent oil-glands in the leaves (RUTACEÆ, HYPERICINEÆ and MYRTACEÆ), a very resinous juice (ANACARDIACEÆ), sticky latex (APOCYNACEÆ and ASCLEPIADACEÆ), a tomentum of brown hairs on the young parts (RHAMNEÆ and STERCULIACEÆ), hood-like stipules which completely cover the bud and leave a scar extending right round the axis (MAGNOLIACEÆ), and peculiar venation (MELASTOMACÆ).

There are other characters which though not common to all the members of a family, or confined to it alone, are yet very distinctive. Practically speaking all trees with bi-pinnate leaves and small

oblong leaflets, especially if every part has a pulvinus, belong to the MIMOSEÆ or to the CÆSALPINEÆ; all herbs with pinnate or trifoliate leaves and pulvinus to the PAPILIONACEÆ; and further all twining plants with pinnately trifoliate leaves provided with a pulvinus to the PHASEOLUS section of the last named family. Most twining plants with opposite simple leaves and sticky latex belong to the ASCLEPIADACEÆ, those with alternate smooth leaves to the CONVOLVULACEÆ, those with rough angular leaves and tendrils to the CUCURBITACEÆ. Herbs or shrubs with decussate scented, but not gland dotted leaves, belong mostly to the LABIATEÆ, those with swollen nodes and no scent, to the ACANTHACEÆ. A tree with pinnately compound leaves and leaflets unsymmetrical at the base is probably one of the MELIACEÆ; if with latex and ring-stipules one of the FICUS group (Banyan, etc.) of the URTICACEÆ. A succulent with latex and pairs of thorns is almost sure to be an EUPHORBIA. Many other cases of close resemblance in the vegetative parts accompanying resemblances in the flowers could be mentioned.

It is this general similarity between the genera of a family which alone justifies us in calling it a *Natural Order*. The vegetative characteristics are therefore very important, and must not be neglected by a student of systematic botany; and they may enable him to determine the order of a plant, when no flowers or fruit are available.

Looking back on the orders we have studied we find that they too fall into fairly well-defined families. Thus the RANUNCULACEÆ and ANONACEÆ are alike

in having numerous stamens and separate carpels arranged spirally on a convex thalamus; the CAPPARIDEÆ and CRUCIFERÆ in the parietal placentation of their ovules; the MALVACEÆ, STERCULIACEÆ and TILIACEÆ in their numerous stamens; the GERANIACEÆ, RUTACEÆ and MELIACEÆ in their prominent disc, which is still larger in the RHAMNEÆ, SAPINDACEÆ and ANACARDIACEÆ. The connexion between the PAPILIONACEÆ, CÆSALPINEÆ and MIMOSEÆ has already (p. 324) been pointed out; the MELASTOMACEÆ, MYRTACEÆ and LYTHRACEÆ resemble each other and differ from the foregoing in their completely inferior ovaries.

And in all these orders the petals are free or, if connected, only slightly so and mostly above, not at the base. We may therefore class them together in one large group of families, the **Polypetalæ,** as distinct from the RUBIACEÆ, COMPOSITEÆ, MYRSINEÆ, SAPOTACEÆ, APOCYNACEÆ, ASCLEPIADACEÆ, CONVOLVULACEÆ, BORAGINEÆ, ACANTHACEÆ, and LABIATEÆ, which are **Monopetalæ,** and differ also from the former class in the greater definiteness of the floral parts (in none for instance are the stamens indefinite) and in other ways.

Of these orders the first two have inferior ovaries, and stamens equal in number to (isomerous with) the corolla lobes; the ASCLEPIADACEÆ and APOCYNACEÆ also have isomerous stamens, but a superior two-carpelled ovary and thick white latex. There are, of course, many more natural orders than the few studied in this book, and with them the groups would be found not only larger but sometimes better defined.

The AMARANTACEÆ, URTICACEÆ and many of the EUPHORBIACEÆ have but one whorl to the perianth, being without petals, and are for that reason often classed in a third section the MONOCHLAMYDEÆ; but the EUPHORBIACEÆ seem in their schizocarpic fruit and the arrangement of the ovule (pendulous with ventral raphe) to be not distantly allied to the GERANIACEÆ; the AMARANTACEÆ are from the nature of the fruit and the curved embryo, usually placed near a family (CARYOPHYLLACEÆ) of the POLYPETALÆ, which has not here been referred to; and for similar reasons the CUCURBITACEÆ are also considered by some to belong to the POLYPETALÆ.

All the plants belonging to these orders are DICOTYLEDONS and very different in almost every respect from the AMARYLLIDEÆ, LILIACEÆ, PALMEÆ, AROIDEÆ, MUSEÆ, CANNEÆ, ZINZIBAREÆ, MARANTEÆ ORCHIDEÆ, which consist of MONOCOTYLEDONS only. The gulf between the two classes is indeed a very wide one and not confined to the seed alone. For, as was pointed out in (p. 68) when studying the germination of seeds, monocotyledons are seldom woody and their larger plants do not often branch above ground. Most are perennial herbs with rhizomes or bulbs, and the latter are very rare among dicotyledons. The leaves are as a rule simple, with parallel or basal venation and entire; or if compound as in the palms, have a totally different appearance. Finally the flowers are usually enclosed, at least in the earlier stages, in a spathe, and their parts are in threes not fours or fives.

Our study of the relationships of plants has thus led to a progressively larger and larger grouping, until

we have come to these two great classes, and has enabled us to separate what, from the point of view of relationship, are the more, from the less important characters; and this is the aim of all scientific classification. It is as if we were examining the branch system of a tree whose stem bifurcates close to the ground and then divides into many branches which end in twigs representing the different species. And just as every twig has arisen, and usually with several others, by lateral development of a twig of the previous year, so probably is every species more closely allied to some than to others of the same genus, and derived with them from some pre-existing species. Into the commonly accepted view of the process by which this has been brought about we cannot enter here; it is closely connected with the extraordinary adaptation of every species to its environment which has been repeatedly pointed out, but has nothing to do with the reaction of the individual to the influences of its immediate environment, and applies in equal degree to plants and animals.

GENERAL

In the introductory chapter plants were referred to as making up with animals the animate portion of our world, differing from the inanimate creation in the ability to feed, grow, and reproduce each its own kind. And though they differ in many respects there are other points of resemblance between the two sections.

Both animals and plants respire, that is give out carbon dioxide as a result of those internal changes in the living substance itself on which life depends.

Both require proteid and carbohydrate food, but the green plant is able to manufacture these complex substances itself, utilizing for this purpose the energy of sunlight by means of the **chlorophyl** contained in its green parts, while animals, being without this power, are ultimately dependent on plants for their food. It is in the possession of this chlorophyl, essentially the same in all assimilating plants, though sometimes masked by some special colouring matter, that most plants differ from animals, and this is the explanation of the stress laid on colour in the introduction (p. 4).

When we come to look more closely we find another attribute of living things, **adaptation.** In a general way every part is wonderfully well adapted for its functions, thus the young parts of the shoot for which the retention of water is important are covered with a waterproof epidermis, while the similar parts of the roots have an absorptive covering of hairs; the axis of shoot and root parts are cylindrical, for their work is to support the leaves and conduct fluids with a minimum of loss, while the leaves whose work is a surface one are flat; the shoot apex is protected by bud scales, which are usually undeveloped leaves that will afterwards expand and be useful as such, while the end of the root has a protective cap, the wearing away of which as it is pushed through the rough soil, is without appreciable loss to the plant.

Not only is each part adapted in a general way to its function, but we find special modifications to suit special conditions. The embryo in the seed takes several forms, and its first leaf may be altered almost

out of recognition, as in palms and grasses. Stems may be thick and erect, or slender and creeping on the ground or climbing up trees. When required to store food and water during an off season, parts of both roots and shoots may be developed as tubers, rhizomes or bulbs. In the case of epiphytes there may be two different kinds of roots, a clinging and an absorptive, on the same plant. Far reaching adaptations are found in plants which inhabit dry and desolate regions, one or two of which have been referred to in chapter xv. We find among fruits and seeds all sorts of variations to aid in dispersal of the seeds, and the most interesting of all are those connected with the visits of insects to flowers encouraged for the sake of the embryo.

All these adaptations are **specific,** that is they belong to the species and are not brought about in the lifetime of the individual plant itself, though abnormal conditions may prevent them appearing to a certain extent (pp. 172–5).

But the individual plant itself reacts to the environment and always, as far as we can see, to a useful end. Shoots react to gravity by growing upwards, and to light by bending towards it. In darkness they grow faster and longer, thus bringing the food-making leaves to the light; and at the same time the leaves, useless in the dark, do not grow to their full size, and the chlorophyl is not developed, the shoot having a pale and sickly appearance **(etiolated).** Roots, on the other hand, are induced by the same external force, gravity, to grow downwards, and are attracted also by moisture; fixation in the ground and the absorption of water being their most important functions.

Response to gravity also causes the stem of twiners to twist round their supports, and the lateral branches of a tree to grow horizontally and so spread the leaves to the light, while, if the main stem is broken, a branch will lose this property and instead grow upright to take its place. All these reactions, being due to differences in the rate of growth of either side of the organ, take place only in parts that are young and still growing.

This power of **reacting** to the external influences, and not always in the same way, but some organs in one some in another; and even the same organ differently under different conditions, is one of the most important attributes of life, which we may now add to those given in the introductory chapter of feeding, growing and reproducing.

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